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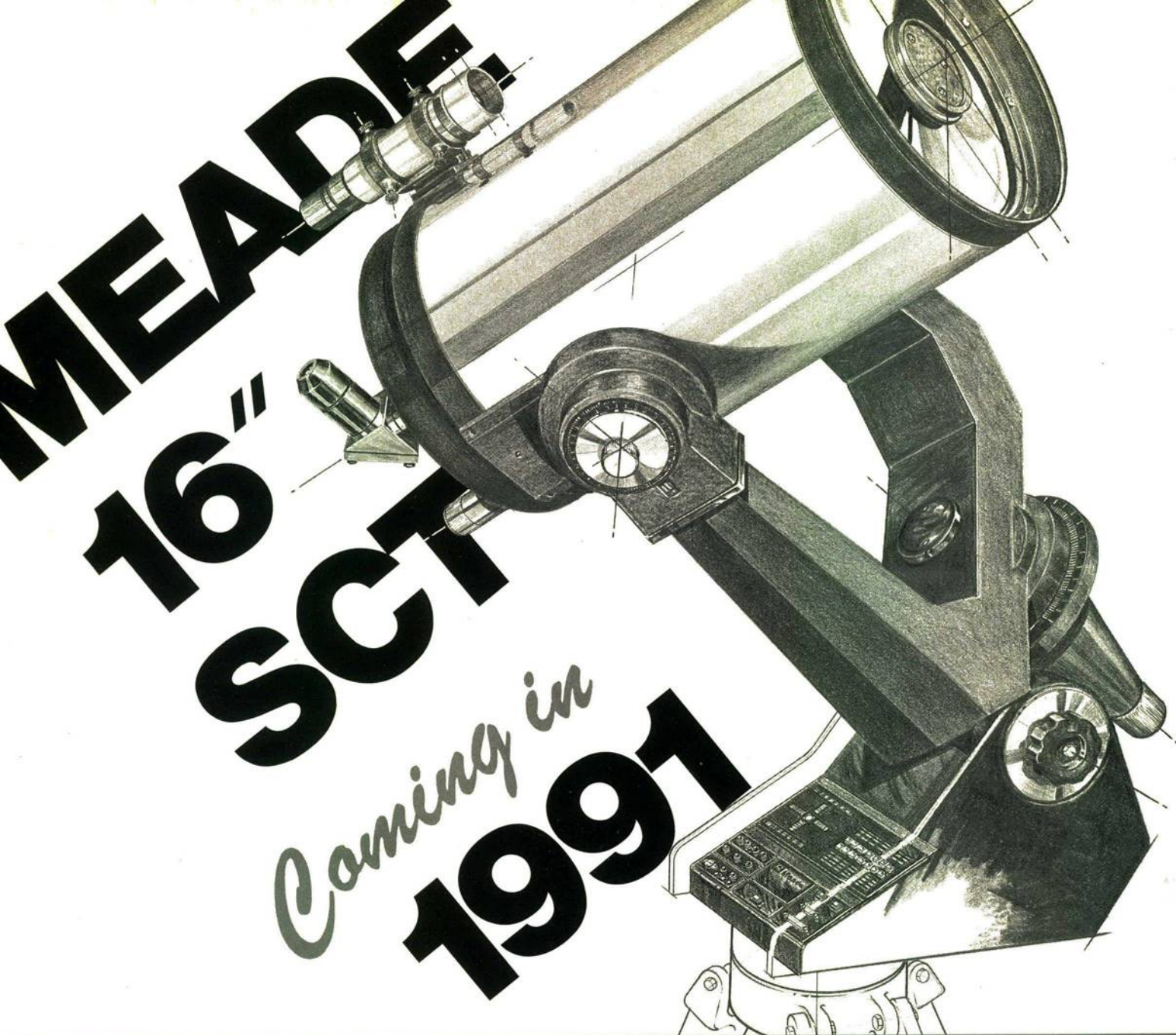
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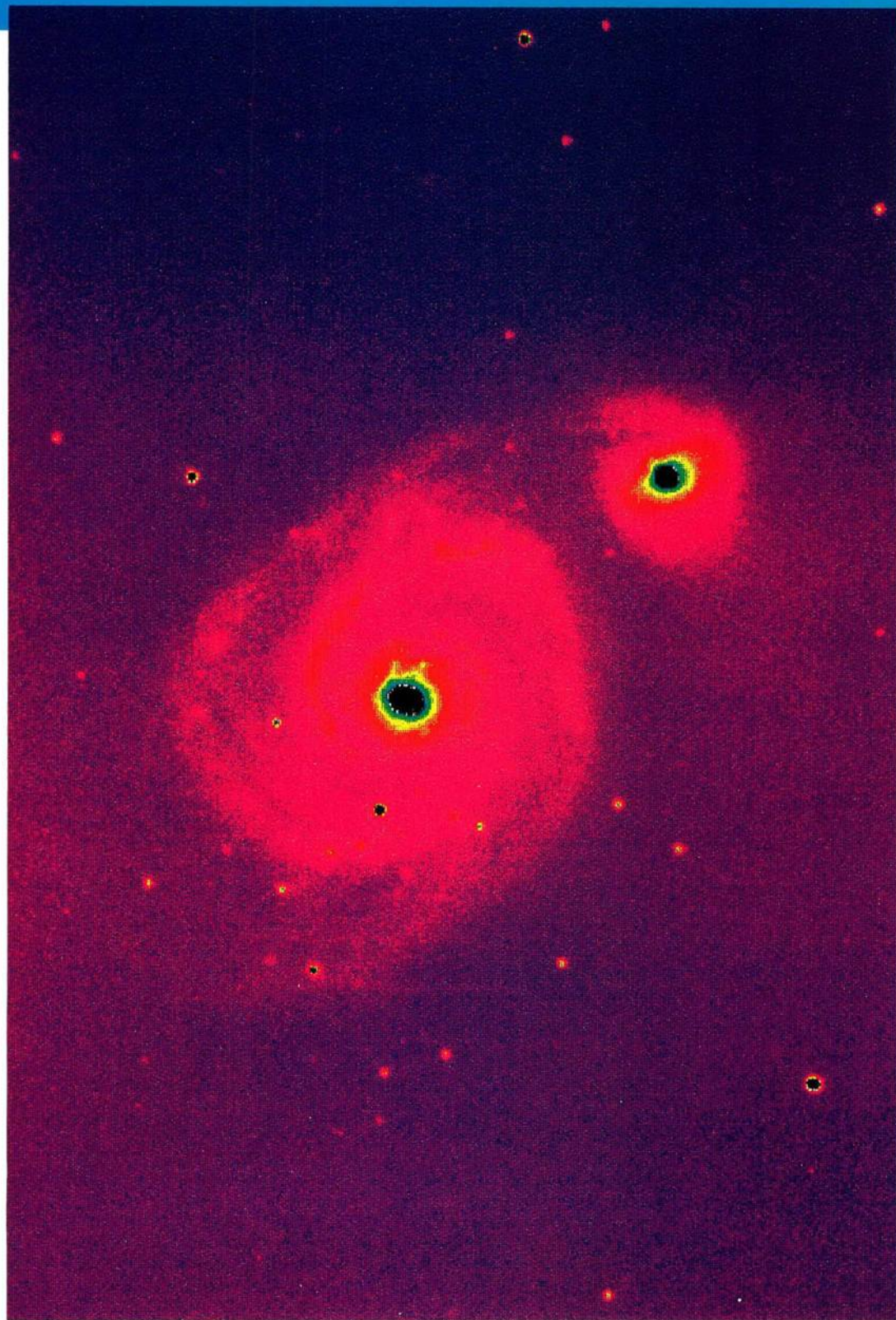
For complete information on the 16" Meade Model 2600, please write to Meade Instruments, requesting Technical Data Sheet #2600, available at no charge.



ON THE COVER:

A geyser sprays a column of gas miles into the thin atmosphere of Triton, Neptune's largest moon. Painting by Michael Carroll. For a comparison of Uranus and Neptune, see page 42.

THE WHIRLPOOL GALAXY swirls in vivid pinks and blues in a false-color digital image by George Fowler. The exposure was 30 seconds with a Photometrics Star I CCD camera on a Celestron 14 telescope.



ASTRONOMY

October 1990

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QUALITY IN THE TELESCOPE INDUSTRY

Last April, at the invitation of their presidents, I spent a week at the manufacturing facilities of Meade Instruments and Celestron International. The purpose of my visit was to examine the quality-control procedures used in manufacturing telescopes. I had free run of each plant. I was free to speak to anyone and ask any questions I wanted. What I found is reported in the twin stories that begin on page 74.

Meade and Celestron are the key players in today's astronomy market. According to ASTRONOMY's market analysis, these firms claim between them at least three-quarters of the dollar volume of telescopes sold in the United States for serious amateur astronomy. Both claim to be the leader in sales.

Through reviews in ASTRONOMY and the editorials and letters in *Telescope Making* magazine, we have brought a great deal of pressure to bear on the telescope industry to improve telescope quality, especially optical quality. This has not been pleasant for the industry, but top quality instruments are vital if amateur astronomy is to remain healthy and strong in this country.

You may have heard rumors that Meade and Celestron are contemplating a merger — or as they describe it, "entering into a joint venture." These rumors are true. A joint letter to dealers by Ira Herman of Meade and Alan Hale of Celestron states, "Both companies believe that certain consolidations are in the best interests of both companies, the consumer, and the astronomy industry. The joint venture would permit operating and purchasing economies which will enable [us] to continue to produce and bring to market quality products at reasonable prices."

I understand that if the Federal Trade Commission approves the merger, no immediate changes will be made in distribution channels or in products offered for sale.

I have full confidence that the management of both Meade and Celestron — whether the companies operate singly or jointly — will continue to invest the necessary time, money, and human effort to bring their customers the best possible telescopes. I greatly appreciate their openness in offering me (and through me, all 300,000 readers of ASTRONOMY) a real behind-the-scenes look at the telescope industry.

In the future, ASTRONOMY will continue to report major developments in the telescope industry. Telescope quality has become an issue too important to ignore, and our concern so far has resulted in improvements that will benefit the industry and the consumer.

Sincerely,



Richard Berry
Editor-in-Chief

ASTRONOMY

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Reviewing the Review

I enjoyed seeing "ASTRONOMY Tests Four Medium-Aperture Refractors" (June issue). I felt it was one of the most unbiased articles of this nature to be published in any magazine and should serve the interests of prospective buyers well.

I would like to point out a couple of things the article missed, however. Ver-nonscope uses apochromatic lenses made by the Astrophysics Corp. The design for our 94mm f/7 refractor, however, is exclusive to us. To our knowledge, we are the only manufacturer of the four offering a three-piece cell for collimation. This allows users to recollimate the telescope, eliminating expensive return trips to the factory.

Although your article mentions that the aus Jena mount is the only one of the four that can be converted to altazimuth, it didn't mention why that would be needed. Comet hunters, casual observers, or daytime landscape observers would all benefit from this feature.

Thank you for benefiting all amateur astronomers by publishing this review article. — *Rodger W. Gordon, Vernonscope and Co., Candor, New York*

I applaud your efforts to enlighten the astronomical community with comparative product reviews, which are long overdue. As an owner of an Astrophysics refractor, however, I was surprised that you didn't mention that the four scopes reviewed all have apochromatic lenses, rather than classical achromatic doublets. While this is obvious to the advanced amateur, it could leave a neophyte confused enough to purchase a Celestron SP-C102 (discounted to about \$1,100), thinking it the same as the Celestron SP-C102F (selling for about \$2,200).

The difference between an achromat and an apochromat is like the difference between my VW Golf with a diesel engine and my brother's Golf GTI, with a sixteen-valve, high output engine. They look nearly identical, but anyone who drives them can immediately perceive the difference. — *Jim Shearer, Albany, New York*

The results of your review of refractors were quite a contrast to the reviews of SCTs. This contrast has made me happy I purchased a refractor as a first telescope rather than an 8-inch SCT.

Areas of your review that need clarification are the sections on optics and vibration damping. It seems that color correction was your primary criterion

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lens edges for maximized contrast.

Over the past few years many companies have jumped on the "Plössl" bandwagon. Some sell "house-brands," while others have added an element to impress you, calling the eyepieces Plössls even though the design resembles an Erfle. Ten years ago, Tele Vue Plössls were designed for sheer performance, not maximum marketing advantage.

Sure, imitators and "house-brands" come close to Tele Vue, but they haven't quite made the grade yet. Tele Vue Plössls still deliver the sharpest fields edge to edge with the least amount of lateral color. Plus, we now include a rubber eyeguard with every model, and maintain our 100% full field inspection process at f/4. Consistency is so good, you'll never have a problem

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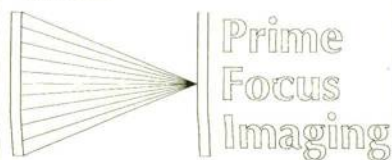
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for the test, and that two lenses (Celestron and Astrophysics) seemed free of color in focus. A more detailed discussion of why you chose one over the other or a discussion of the merits of each design (fluorite vs. non-fluorite) seems in order. With mountings, two (Celestron and Astrophysics) used mountings by the same manufacturer. Presumably, one mounting was a heavy duty version of the other, yet scored worse in damp times. What method was used to ensure the same force was applied to each of the scopes? If the method was not the source of the difference, what was? — *Jeff Morgan, Oak Forest, Illinois*

ASTRONOMY used a vibration test identical to that used (and recommended to us) by the manufacturers. Because vibration decays exponentially, almost any tap will do. Regardless of who they are manufactured by, different mountings show different degrees of solidity.

Observing from the Glow

I was struck by Peter Manly's article "Beneath the Neon Lights" (June issue). Like Manly, I live in the Phoenix area and because I'm 13 years old, I hardly ever get the chance to observe from a dark-sky site. Nevertheless, I have seen more than half of the Messier objects and many NGC objects from my backyard. The planets show up quite well from hazy city skies, better I think than they do in the country. And the Moon has been a great favorite over the years. I think amateurs who live in cities should pay more attention to what they can see instead of what they can't. — *John Barentine, Phoenix, Arizona*

Watching Hubble Go

Thank you for presenting some of the breathtaking photographs of the *HST* deployment in the July 1990 issue. As one of the myriad of people working on this mission for years, these pictures brought to reality a major milestone. Your caption on page 36 is in error, however: *HST* is above Salar de Uyuni in Bolivia, not Peru. The dark blue lake at bottom right is Lake Titicaca. The body of water labeled as such in the photo is the Pacific Ocean. The confusion may have resulted from Northern Hemisphere chauvinism: as printed, the photo has south at top. — *Glenn Schneider, Space Telescope Science Institute, Baltimore, Maryland*

Lunar Transient Phenomena Spotted

As director of the lunar section of the

Latin-American Astronomical League, I received information of recent lunar transient phenomena (LTP) that occurred on February 20, 1990. Brazilian observer Heliomarzio Rodriguez was observing with a 4-inch telescope and saw a brightness in the dark side of Promontorium Olivium, at 7:29 p.m. local time. The brightness of the spot gradually increased until 7:34, by which time the area had regained its normal appearance. We would like to hear of any reports of this LTP or any others for our files. — *Jose Manuel Barreiro, Latin-American Astronomical League, Alcala de Henares, Num. 6 Esc., IZDA 9cD, 18008 Granada, Spain.*

Measuring the Coolest Stars

I found James Kaler's "The Coolest Stars" fascinating (May issue), but I wonder about one statement made toward the end of the article. Discussing the phase difference between maser peaks originating in the interior of the star as opposed to those later generated in the surrounding molecular cloud, Kaler asserts "to find the shell's diameter, all astronomers have to do is measure the time between the maximum of one peak and that of the other and divide by the speed of light." Wouldn't the correct method be to multiply by the speed of light? This would yield an answer in units of distance, whereas dividing does not. — *Joe Klotzman, Encino, California*

The article should have indicated multiplying time by the speed of light to obtain the correct answer. We humbly apologize for the inconvenience.

Tiny World in Vast Space

The skies were dark back then, even in town, and the feeling of wonder was incredible. Lying out in a summer sleeping bag with my Dad, we scoured the heavens and found dozens — thousands, or so it seemed — of stars and planets. Occasionally a meteor would kiss the fabric of the sky.

As I grew, my interests expanded toward space exploration. I followed every televised launch religiously. Interests further diversified until I majored in geology in college and that carried me out into the work force, yet I still had a burning interest in exploring the sky. Viewing the cosmos gave an awakening feeling of discovering the wonder of life and where it fits in the grand scheme of the universe. Geologic time was astounding, but seemed quite comprehensible

DEAR MR. NAGLER,

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis**. Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly \$20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis**. Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■



Photo by Tom Orzechowski

AN OWNER'S VIEW:

Genesis

was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "...but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend across the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

In case you could have possibly missed me, I am totally enthralled with

DEAR MR. NAGLER:

LEDLOW:
(From one owner to another, we present two unsolicited letters about Genesis)

Having purchased a Genesis and barely given it a trial, I can believe that your "Dear Mr. Nagler" letter is genuine: not ad agency copy. Also using the Nagler 7mm eyepiece, I am hooked. Champagne tastes suddenly acquired on a beer budget! Hope my 8" SCT doesn't sulk!
-Roy Woodland, ONT.

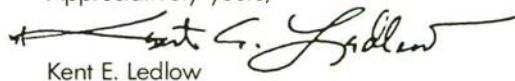
P.S. But Mr N. in a word WOW!!

...praise your design including the fluorite element as a totally internal component, inaccessible to dew, condensation or scratches. ■



It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,


Kent E. Ledlow

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when compared to astronomical time-
scales.

After I became a high school teacher of earth science classes, it dawned on me that among all the richness of the universe lies a miserable poverty. This poverty is a philosophical one, one that is striking society everywhere on Earth. In our constant pursuit of more — money, property, power, etc. — our society has lost a sense of belonging to a place in the vast network of the cosmos. It seems ironic that ancients who gazed up at the stars under a black sky probably thought more about the origins of life and the universe than most people in today's more educated but plasticized, nearsighted civilization. The era of MTV and glitzy newspapers that cater to today's fast-paced lifestyle has totally overcome science. People benefit from science but pay no attention to it otherwise. Can we turn our backs on science and society and forget that we live on a tiny world in vast space? I hope not. — *Mark Bailey, Lower Lake, California*

Which Came First: Electric Field or Magnetic Current?

Having just read the June 1990 issue, I can't help but react to the marvelous article "The Magnetic Milky Way" by Gerrit L. Verschuur. In his key contention, Verschuur asks, "Which came first, the magnetic field 'chicken' or the electric current 'egg'?"

This curious point will be debated by physicists and astronomers forever, but it is comforting to remember something once uttered by Sir James Jeans. "Matter is not pure thought," said Jeans, "but it is the electric record of thought." If Jeans is correct, it's comforting to know that perhaps it doesn't matter which came first, anyway. — *John A. Young, Menard, Texas*

Mission to Pluto?

Alan Stern's article "2001: A Mission to Pluto" raised some very good points ("Viewpoints," July issue). It would certainly be nice if NASA could launch a Pluto flyby mission sooner than eleven years from now. I think a relatively simple, Voyager-type craft would do nicely, and it should be possible to convince Congress to spend that relatively small amount of money. — *Russell Clousing, Lansing, Michigan*

After All, Theories Are Theories

Because astronomers (and we psychiatrists) are human, as Gerrit Verschuur warns ("Do Astronomers Believe in

Things That Don't Exist?" Viewpoints, August 1990), "we often get so carried away by our theories that we forget that even the best of them may have little to do with reality." On the early maps of Africa, the Dark Continent, cartographers used drawings of elephants, lions, and tigers to cover *terrae incognitae*.

Upon encountering a hunk of the unknown, we seek a reassuring explanation. But finding one brings only short-lived relief; peeling away one petal of an artichoke discloses further unknowns beneath. And if, as is usually the case, we cannot solve an unknown, our consequent unease urges us to speculate. Speculation soon transforms into assumption, thence to presumption, and on to dogma, brutally defended.

Let me propose a maxim: The level of validity of a scientific tenet is inversely proportional to the level of vituperation that its adherents direct against those who would test it. — *William F. Sheeley, Phoenix, Arizona*

What a refreshing article Gerrit Verschuur wrote! Many have said there is no such thing as a truly objective opinion, and I've been tempted to believe it. Now it's obvious there's at least one astronomer among us who has a firm grip on his imagination as well as his pen.

The danger to science from "clever" theoreticians strikes me as similar to that posed to the church by theologians trained in primitive logic but unable to teach their way out of a paper bag. We should be careful what we listen to from theoreticians in any case, because the universe is complicated enough to learn about without having to "unlearn" what we believe later. — *Doug Penner, Santa Cruz, California*

Keep Those Asteroids A'Comin!

I hope you don't think that your excellent asteroid charts go to waste. [No way! — ed.] I use them every month and thank you for providing this service to your readers. Each issue I take my 11x80 binoculars and find every asteroid brighter than 10th magnitude. My latest victim was 8 Flora, so gracefully featured in your June issue. Keep the asteroid charts coming! — *Benjamin Willett, Buckner, Kentucky* □

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on astronomy in general and articles in particular. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187.

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Viewpoints

A BEGINNER'S GUIDE TO STAR PARTIES

by Karen Saunders

Ah, star parties. What else can give you such enjoyment — such insecurity — such terror?

Your first star party looms on the horizon and because you have no idea what it's all about, you're filled with anticipation and dread. Just what, exactly, does one *do* at these things?

Don't panic. They're fun and one of the few places left where you can get away with acting like a blithering idiot. Moreover, it's so darn dark, no one can see what you're doing or knows who you are.

If you keep a few hints and (unwritten) rules in mind, you'll have the groundwork for a fantastic hobby. And *relax*, for heaven's sake. You aren't expected to know everything about astronomy on your first night. The quiz on the Moon's geocentric parallax comes later.

Star party etiquette; or, how to listen to Pavarotti — or 2 Live Crew — without engendering violence.

Now this can get interesting. Amateur astronomers have gotten so touchy about the subject of music at star parties that the poor old Bill of Rights is starting to resemble a Ping-Pong ball — and still nothing is settled. A little common sense on your part should keep you out of the controversy.

Ask those in the listening area if they object to your selection. Don't be offended if you get vetoed. They may be doing serious work with their telescopes and shouldn't be distracted. Check out light classical or New Age mood and meditation music. Most people won't object if it is played at reasonable volume. But if you can't get everyone to agree, use headphones.

Going from point A to point B.

Before you try to walk around much, give your eyes time to adjust to the dark. Use a flashlight with a red filter. You can make your own by covering the lens with red paper or cloth; just be sure the light's dim enough. You'll know it's right if you have to walk at sub-light speed to get anywhere. Watch out for electrical cords, telescope legs, chairs, and other assorted items, human or not, lying on the ground.

Don't touch a telescope someone is looking through.

If that person is looking through the eyepiece, he or she could be injured. And in any case they probably spent considerable effort getting an object centered — and you just knocked it light-years out of sight. This does not make for happy astronomers.

Why you can't see anything after looking at the Moon for an hour.

You're seeing reflected sunlight — I hope you have as much fun as I did figuring that one out. Beg, borrow, or buy a Moon filter if you have a telescope. In a pinch, use sunglasses, or try looking at only part of the Moon to cut down on the brightness. And look for just a few seconds at a time.



How to avoid backache.

First admit that you're not sixteen anymore and that your back really does hurt. Then adjust the legs on the tripod so you can sit while using the telescope. Remember to get up and walk around periodically to unkink those stiffened muscles.

The thrill of looking for the Owl Nebula with a 60mm refractor.

Don't fall for the gorgeous pictures of nebulae in the books and magazines — they're not what you're going to see because they were taken with a camera set for time exposures. Study books and magazines to learn the brightness and



Above - NGT-18 f/4.5 photo of M51, 30 minutes on Ektar 1000 by Dave Young, Colorado.

Below - NGT-18 f/4.5 photo of M13, 10 minutes on Ektar 1000 by Dave Young, Colorado.



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size of objects. If they say something is dim or poses a challenge — believe me, they mean it. I spent three months looking for the Owl Nebula with a small refractor and learned a whole new meaning for the word frustration. Even when a kind soul found it for me in a 12-inch reflector, I still had to be told I was really seeing it.

Smoking.

Like music, this is another hotly debated subject — no pun intended. If you smoke, there are several things you can do to avoid offending others. Watch where you exhale. You know what your windows and mirrors look like at home. Don't let that yucky, yellow gunk get on someone's telescope optics; you can't wipe them clean as you can a window. I smoke, but I hate to see a lot of cigarette butts on the ground. Carry an ashtray with you and use it. You might have to take it home full for safety's sake. Shield the flame when you "flick your Bic." Besides startling anyone near you, the flame will ruin his or her night vision.

How to stop shivering with cold.

The weather report always lies. No matter what time of year it is, I bring gloves, a coat, a hat, and my all-time favorite, earmuffs. My first star party was on an August night. The temperature had been in the 80s all day but by 1 a.m., I was miserable from the cold.

How to handle The Question: Have you seen any UFOs?

Don't think this won't come up. I heard it asked twice at my first star party. People are simply curious about the unknown and are trying to find answers. (You got a *better* reason for fooling around with backyard astronomy?) I've talked with amateur astronomers who won't discuss UFOs beyond saying, "Don't be ridiculous." Others have said they're open to the possibility but waiting for concrete proof. Several admitted they're convinced UFOs are real. One amateur astronomer even whispered that he's investigating contact and abduction cases. He also whispered that I'll get a personal lesson in obscure jungle tortures if I divulged his name.

This astronomy business is pretty serious stuff, so you don't want to start telling everyone about your mother-in-law (who indeed does happen to be from Venus). What can you do about curiosity on the subject?

Accept the fact there's no proof either

way that we're being visited by little green (or blue, or whatever) men from another planet. It's up to you what you choose to believe as long as you allow others their choice — and don't impose yours as the only right choice. Believe what you're comfortable with, but at least read up enough on the subject so you can provide an intelligent answer. If you see something strange, ask an experienced observer for an explanation before you jump to the little-green-man conclusion.

Why it's OK to show up with a K-mart telescope.

There are times when you have a legitimate reason — excuse? — to use one of those little beauties that pretend to be telescopes. Such as: you bought it before you knew better. You don't have access to books or magazines offering quality scopes at reasonable prices. (Of course, since you have this magazine in your hands, you can't get away with that any more.) You just *have* to have a scope and you can't wait for one to be delivered. You had no intention of buying one, but that last garage sale offered a deal you couldn't pass up.

This last reason fits me. I bought an old clunker refractor that way and the thing got me so hooked on astronomy I jeopardized my marriage by buying a 12.5-inch reflector when I outgrew the refractor. The marriage is still shaky though. Now I have to fight for possession of the darn thing whenever we go stargazing.

How to get invited back.

When you observe your first star through a telescope, don't broadcast your disappointment that it doesn't have five points. (Yeah, like the Easter Bunny and the Tooth Fairy, this is just another story you were fed as a child.) Likewise, don't yell "Look at this crater!" when you take your first good look at the Moon. Honest, everyone there has seen it, mapped it, measured it, memorized it, and thoroughly had their fill of it. Nor will you win a popularity prize by remarking that you thought the Andromeda Galaxy would be more than a smudge. As you get into astronomy more, you'll realize how fantastic that smudge really is.

Ask for advice about astronomy books for beginners. If you get twenty titles, and you don't have a rich uncle, go to the library and look at all of them to decide which will help you the most. Never be embarrassed to ask questions, no matter how stupid you think they

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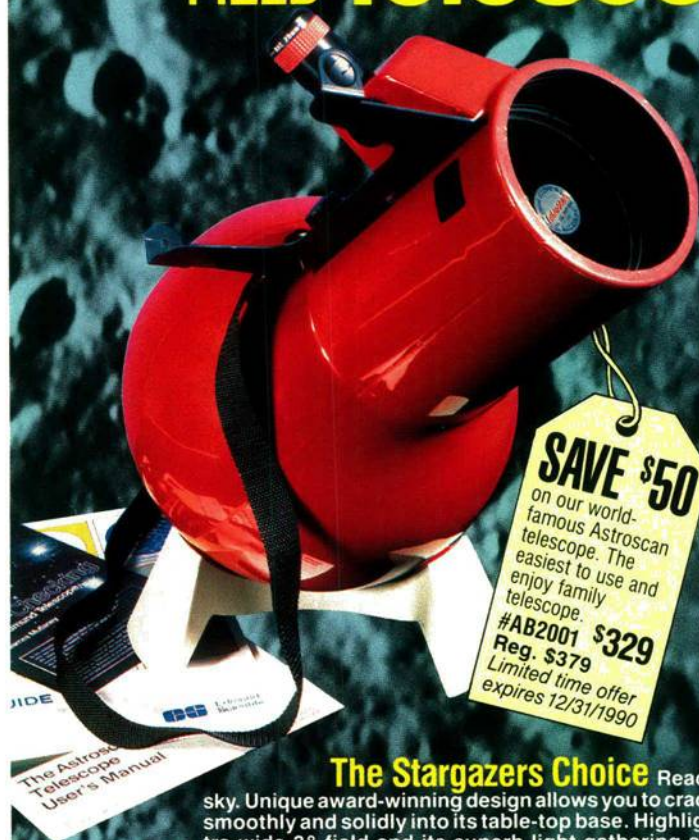
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sound. At one time, no one there knew any more than you do right now. There are no dumb questions, just uninformed people.

Know how to operate your telescope.

No matter where you bought your scope or what you paid for it, it's going to scare you the first few times you use it. So, in daylight, take the scope and instructions outside. (You do have the instructions, don't you?) Study them both thoroughly in the light because you'll be hopelessly confused if you try to set it up for the first time in the dark.

If something doesn't move freely, don't force it. Look for a wing nut, a bolt, a screw, a mechanic — *something*. You have no idea what depression is until you strip a metric thread and then waltz down to the hardware store thinking to replace it. Ha! Maybe if you live in Japan.

Level the tripod legs and mark them. Using the red flashlight, it'll be easier to set up in the dark — except on bumpy ground. If your telescope came with setting circles, forget about them for now — unless, of course, you're an experienced celestial navigator or a close relative of Carl Sagan. Contrary to popular opinion, you don't have to use these things until you work up the nerve. Just be sure you can move and aim the scope smoothly.

How do I take care of my telescope?

The same way you'd take care of the Hope Diamond. Please don't let the kids take it apart to see how it works. I have two small refractors in my garage that my husband and I can't make into one good scope. It seems the kids can't remember where they put the pieces.

If any of the telescope's glass surfaces get dirty, don't wipe them with tissues or towels. It's amazing how easily they scratch. The same goes for dew. Don't wipe it off — there'll be tiny bits of grit on the lens in addition to the dew. (Besides, if it's that damp outside, you should be in bed anyway.) And remember to let the dew dry before you cover the scope. Those spots will be there forever otherwise. If the optics are so dirty you're seeing new craters on the Moon, just gently blow the dust away. At most, until you have a better idea of what you're doing, use a soft camel's hair brush to remove dust.

If you have one of those Sun filters that screws into the eyepiece or fits over it — whack it with a hammer and throw away the pieces. These filters are dangerous to leave lying around because

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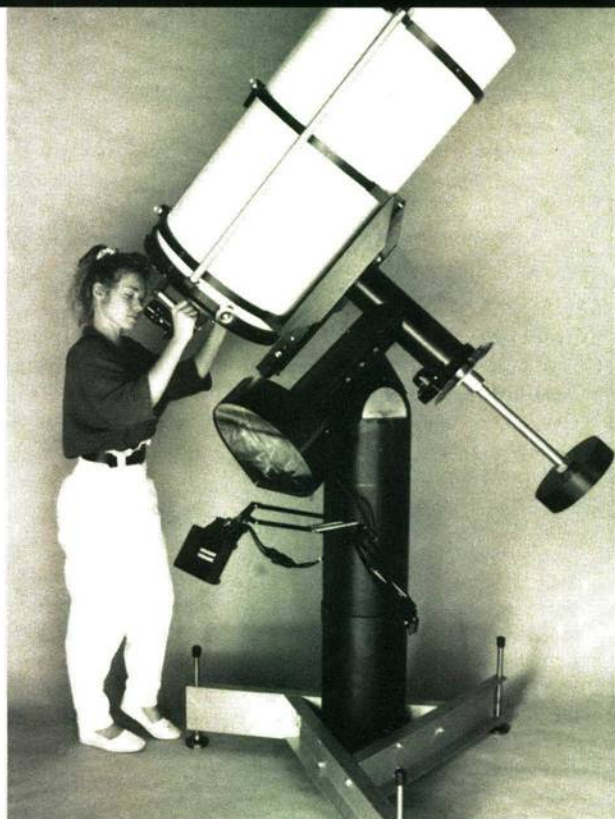
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someone may unwittingly try to use one. The problem is that the little filter intercepts all the concentrated solar heat and the glass can crack while your eye is looking through it. It's best to learn how to view the Sun from an experienced observer.

Where to get help.

Try looking under Telescopes in the phone book. This can lead you to astronomy clubs. Ask at the nearest planetarium or observatory. Try stores that specialize in optics. (A random call to one put me in touch with an amateur astronomer who happened to own the store.) Ask science teachers at the local schools. Try a museum or ask the library reference desk. Take out an ad in the local paper asking for someone who knows anything about astronomy. Try the classified-ads section under Photography, Cameras, or Hobbies. If you can't find anyone locally, start your own group — a sort of a learn-as-you-go idea.

Where to use your telescope.

This can cause problems if dark skies aren't available locally. The days of hiking out to Farmer Friendly's place are gone. Nowadays, a farmer may shoot first and not even bother asking questions later. Here's what you can do if you can't go with a regular astronomy group. Try asking Farmer Friendly if you can use his property; maybe the old boy is mellowing with age. Or call your local parks department to get a permit for after-dark use. In any case, take at least two other people with you, and it wouldn't hurt to let someone else know where you'll be and when you expect to get back.

Well, there you have it — just about everything you need to make your first star party a success. As you advance in amateur astronomy and can explain why flocculi of the chromosphere show up in spectroheliograms (but why you'd want to is beyond me), don't forget the thrill you felt at your first look through a telescope. Let astronomy be a constantly changing experience for you, and introduce others to the hobby, especially children.

I promise that all your patience in putting up with their endless questions — Why doesn't the Moon fall down? What does God shoot with the shooting stars? — will be rewarded when they see the Moon for the first time through a telescope. The utter silence and look of astonishment on their faces will make it all worthwhile. □



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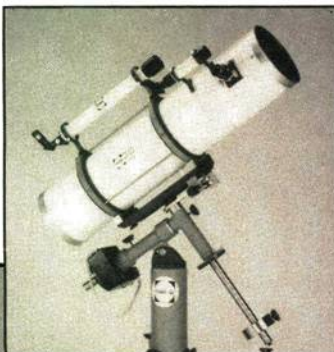
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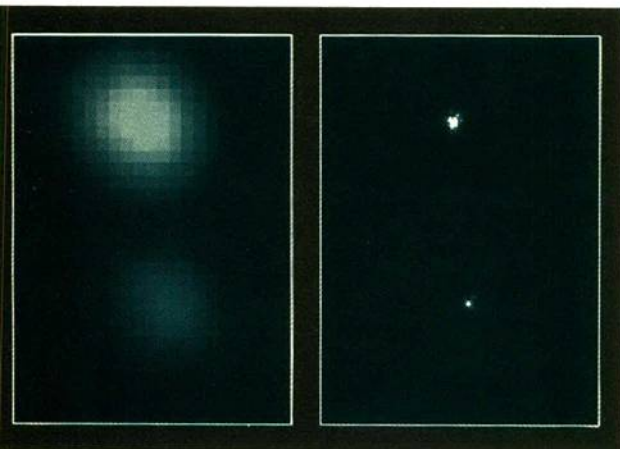
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ASSESSING HUBBLE'S TROUBLES

NASA's *Hubble Space Telescope* suffers from an error in one of its mirrors that significantly reduces the short-term capabilities of the orbiting observatory. Only some fifty percent of the planned first-round observations can still be accomplished, according to preliminary estimates by the Space Telescope Science Institute. Mission planners nevertheless remain confident that *HST* can make major discoveries in its current state, and with a second generation of instruments planned for the future, they feel the telescope can meet all of the mission's original scientific goals.



FIRST LIGHT for Hubble's Faint Object Camera came shortly before a major flaw in the telescope's optics was discovered. The diffuse halos of light surrounding the stars (part of the open cluster NGC 188) in the *HST* image (right) are characteristic of spherical aberration, though note that the resolution is still substantially better than that from a 2.5-meter ground-based telescope (left). NASA image.

The error in the mirror produces spherical aberration, which means light striking the mirror at different distances from its center is not brought to a common focus. The original specification for *HST*'s optics called for 70 percent of the incoming light to be focused within a radius of 0.1 arcsecond. In reality, the telescope focuses 70 percent of the light inside a radius of 0.7 arcsecond. About 15 percent of the light is focused into a small core less than 0.1 arcsecond wide; the rest is spread out into a halo about 1 arcsecond across, which is

comparable to ground-based images.

Lost in all the publicity and controversy surrounding *HST*'s problems, however, is the fact that even now the telescope retains many capabilities that surpass those of any ground-based or orbiting observatory. In a position paper prepared for NASA, the *HST* Science Working Group and the *HST* Users Committee stated: "Loss of image quality has damaged some of [*HST*'s many observational] modes, but many remain wholly or largely intact. Temporarily being able to use only certain of these modes will not alter the fact that we will still be able to do forefront science 100 percent of the time, but the initial scientific emphasis will have to be different."

The area that will probably receive most of the revised emphasis is ultraviolet astronomy, which cannot be done at all from the ground. *HST*'s light-gathering power, resolution, and instrumentation far exceed those of the *International Ultraviolet Explorer* satellite (the other major ultraviolet telescope in orbit), and should provide astronomers with high-quality images, spectroscopy, and photometry at ultraviolet wavelengths.

The optical problem affects each of the six *HST* instruments differently. Most seriously damaged is the Wide Field/Planetary Camera (WF/PC), the one that promised to deliver extraordinarily detailed images of the cosmos in visible light. Some 40 percent of the planned first-round observations made use of the WF/PC, but only about 10 percent of those observations now appear to be salvageable.

The loss of the WF/PC's imaging capabilities postpones many important and exciting observing programs, including two of the mission's three key projects — determining the distance scale of the universe and making deep surveys of the sky to detect faint objects. Fortunately, one of the planned second-generation instruments is the Wide Field/Planetary Camera II, and it can be designed to completely correct

for the mirror's error. This is essentially the same thing an optician does when he or she makes glasses to correct a vision problem. A shuttle mission to install the WF/PC II is currently scheduled for June 1993.

The Faint Object Camera (FOC) originally had the highest resolution of any of *HST*'s cameras, but the mirror error effectively limits its capabilities. Roughly 50 percent of the FOC's observations remain viable, however, mostly those involving ultraviolet imaging. Visible-light imaging with the FOC will now achieve resolutions only about as good as ground-based telescopes can provide, so those observations will be dropped.

The ability of the two spectrographs on board — the Goddard High Resolution Spectrograph and the Faint Object Spectrograph — to obtain ultraviolet spectra remains largely intact. However, the optical problem means that light striking these instruments is spread out more than originally planned, so they will either have to target brighter objects or observe them for a longer time. The spectrographs will carry out the mission's third key project — obtaining ultraviolet spectra of quasars to study the properties of galaxies that lie along the same line of sight.

The High Speed Photometer should be able to carry out a good portion of its program of measuring the brightness and variability of objects. Once again, observations made in ultraviolet light will be the most valuable. The only observations that probably can't be done are those that require a high signal-to-noise ratio.

Finally, the three Fine Guidance Sensors that help locate targets for *HST* should be unscathed by the mirror error. That's good news to astronomers interested in astrometry, the study of the positions and motions of stars. One prime area of research scheduled for the sensors is the search for extra-solar planets. Astronomers hope to detect the presence of these planets by observing the telltale wobbles in the motions of stars caused by the planets' gravitational influence.

The Space Telescope Science Institute is currently making a technical assessment of all first-round observing proposals to see how they will be affected by the optical problem. Those that will provide nonredundant scientific data will go forward, while those

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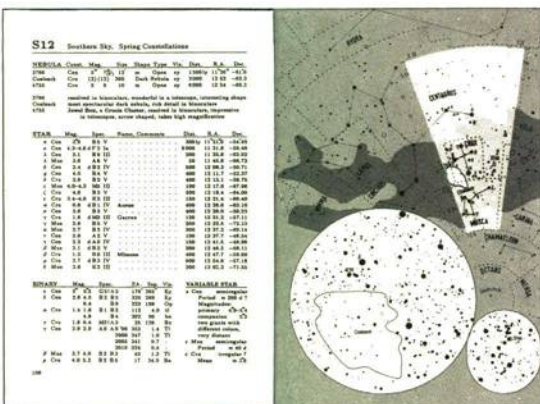
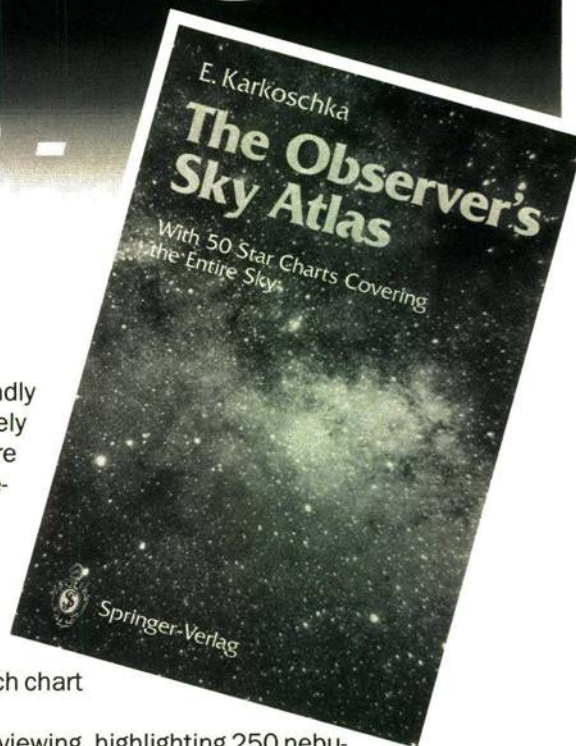
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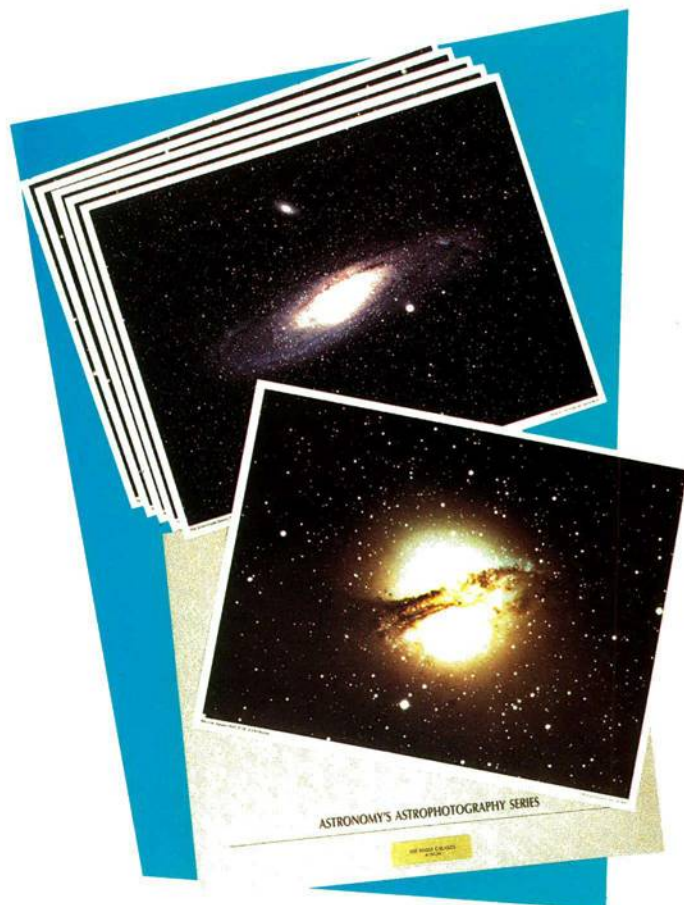


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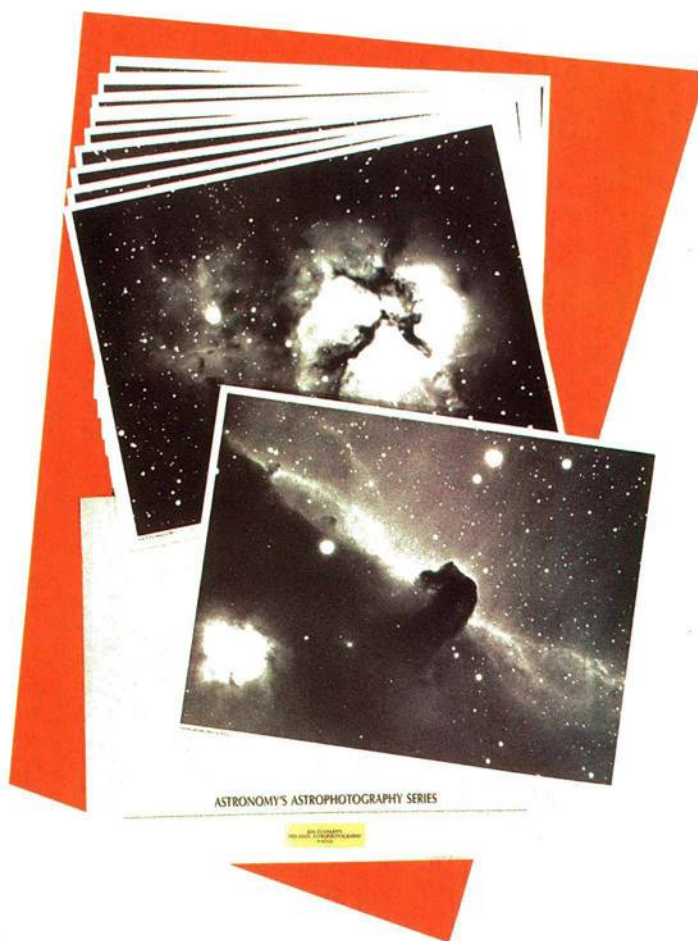


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that need some modification will go back to the observer for possible reworking. Some of the approximately sixty proposals that were originally "flying standby" — accepted in the first round but not expected to be carried out unless *HST* got ahead of schedule — may be brought in to take up any slack that develops.

Although astronomers can't fix the focus problem, they can design new instruments that correct for it. The first of three planned second-generation instruments to fly will be the WF/PC II. With it in place, *HST* will produce the high-resolution images that so much of the mission depends on.

Two other second-generation instruments are under development. The Space Telescope Imaging Spectrograph, which will replace *HST*'s current spectrographs and expand the telescope's spectrographic power, and the Near Infrared Camera and Multiple Object Spectrograph, which will extend *HST*'s capabilities into the infrared part of the spectrum, are scheduled for launch in the mid-1990s.

There's no question that *HST*'s problems deal a major blow to the astronomical community. Although many new discoveries may be made in the next few years, the mirror error severely compromises the telescope's short-term prospects. But most astronomers remain optimistic that by the time its 15-year mission is up, the *Hubble Space Telescope* will have fully realized its ambitious goals.



PLUTO AND CHARON ARE CLEARLY RESOLVED in one of the best ground-based images yet obtained of the pair. This infrared CCD image was taken on May 20, 1990, at the Canada-France-Hawaii Telescope during engineering tests with the new DAO/CFHT High Resolution Camera. At the time of this 90-second exposure, Pluto and Charon were only 0.88 arcsecond apart. Photo courtesy of Dominion Astrophysical Observatory / Canada - France - Hawaii Telescope High Resolution Camera Team.

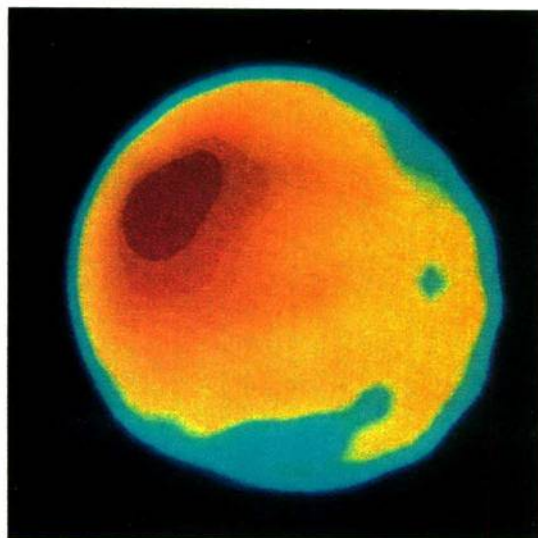
RADIO IMAGES OF MERCURY SHOW TWO 'HOT POLES'

Radio images of Mercury taken with the Very Large Array at 2 and 6 centimeters wavelength have revealed two places, now dubbed the "hot poles," where the Sun's heating effects fall most strongly on the planet. The two regions, which cover about 15 percent of Mercury's surface, are 180° apart on the planet and lie near the equator. The observations were made by a team of five astronomers from several institutions in New Mexico led by Jack Burns of New Mexico State University.

The surface of Mercury can reach temperatures of about 700 kelvins (800° F) when the planet is closest to the Sun (perihelion). The radio images, however, mapped the temperature of the subsurface at a depth of about three feet, where the peak temperature measured was about 375 K (215° F) — some 270 K (490° F) warmer than the temperature of the layer elsewhere on Mercury. The subsurface generally stays cool because the porous, loosely-compacted surface insulates it. Because of this effect, temperature differences in the deep layer reflect only the long-term heating patterns.

The reason why heat collects at two hot poles instead of spreading evenly around the planet's equator is that Mercury's day and year are coupled in an eccentric fashion. The result is that the two "hot pole" regions face the Sun alternately at every other perihelion, when solar heating is more than twice as strong as at aphelion. Despite the insulating layer at the surface, the rhythmically repeated heating at these two points has slowly warmed the subsurface.

A second outcome of the observations, puzzling in its implications, is that scientists now have a good figure for the heat flow from Mercury's deep interior: essentially, there appears to be none. This indicates that Mercury has no large molten core, a surprising result because a large molten core had been widely supposed to be the source of the magnetic field that Mercury is known to possess. What this finding will do to planetary scientists' models for Mercury is so far undetermined.



ONE OF MERCURY'S two "hot poles" shows red in this image taken with the VLA radio telescope.

THE ENERGETIC SURROUNDINGS OF SUPERNOVA 1987A

Nearly four years after the explosion of supernova 1987A in the Large Magellanic Cloud, astronomers continue to scrutinize the supernova and its environs. The latest discovery shows clearly that 1987A lies inside a series of expanding shells of interstellar material that surround the neighboring Tarantula Nebula.

John Meaburn of the University of Manchester in England made the discovery based on long-exposure photographs he took with the 1.2-meter Schmidt camera at the Anglo-Australian Observatory in New South Wales, Australia. The photos were taken through a filter that isolates the red H-alpha light emitted by hydrogen gas. The Tarantula Nebula is an immense region of luminous hydrogen gas, from which a multitude of stars have recently been born and continue to be born.

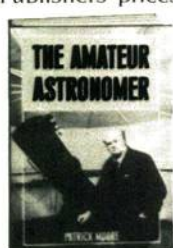
Meaburn's images not only show the Tarantula and the expanding shells of interstellar matter but also reveal that the entire complex of gas, dust, and young stars is enclosed by a huge shell more than 3,000 light-years in diameter. Astronomers think that the only way these interstellar bubbles could form is through a succession of supernovae combined with high-speed stellar winds streaming from hot, young stars. Supernova 1987A is simply the latest in a long series of stellar explosions in this region dating back over the past billion or more years.

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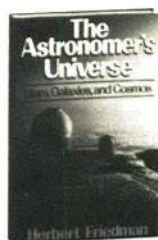
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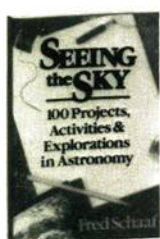
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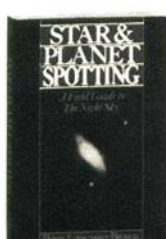
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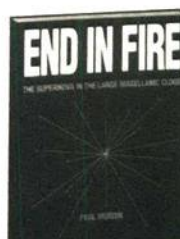
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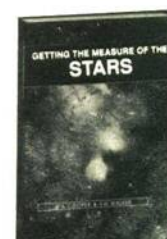
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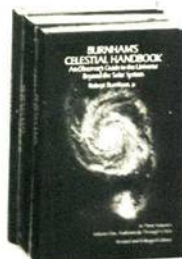
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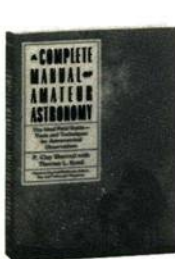
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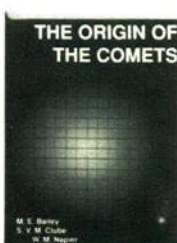
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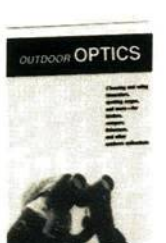
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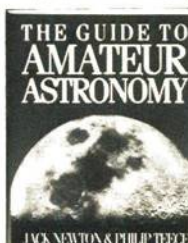
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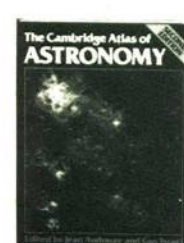
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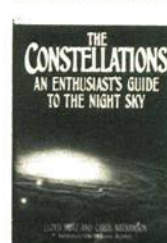
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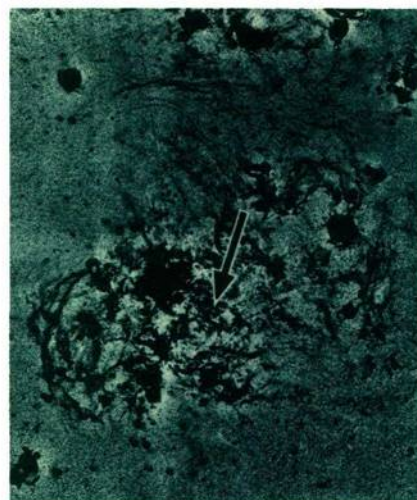
L-CP3

In a separate experiment, Meaburn observed the immediate vicinity of supernova 1987A with the 3.9-meter Anglo-Australian Telescope. He found two shells of ionized gas expanding away from the site of the supernova, the larger one more than 100 light-years in diameter.

Closer in there appears to be a lobe-shaped cavity — a region of virtually empty space — centered on the supernova. It's about 25 light-years across and is expanding at a rate of hundreds of kilometers per second. This observation ties in nicely with theories about the past history of the progenitor star and helps pin down the latter stages of that star's evolution. In the final stage of evolution before the supernova ex-

EXPANDING SHELLS OF HYDROGEN GAS centered on the Tarantula Nebula envelop the site of supernova 1987A (arrow). Glowing hydrogen appears black in this negative image, and the Tarantula lies to the upper left of the supernova's location. Photo courtesy John Meaburn, University of Manchester.

plosion, the star was a hot blue supergiant, the kind of star that sheds material in a fast-moving, rarefied wind. Prior to that, astronomers think the star was a cool red supergiant with a slower but denser stellar wind. The shell around the observed cavity results when the fast wind from the blue supergiant phase slams into the slower-moving wind from the red supergiant phase.



Space News

WILL JAPAN COLONIZE MARS?

"By the year 2057 there will be 150 Japanese settlers living on Mars." So declared Yoji Ishikawa, a scientist from the Ohbayashi Corporation of Japan. He made his remark at the fourth Case For Mars conference held last June in Boulder, Colorado.

The theme of the well-attended conference was the international exploration of Mars. Delegates from most spacefaring nations were there, representing a number of NASA facilities and U.S. aerospace companies, the European Space Agency, France's CNES (Centre National d'Études Spatiales), the Soviet Union, and Japan. Most set forth alternative approaches to exploring and settling the Red Planet.

Some of the most controversial and innovative views came from the Japanese participants. As outlined by Ishikawa, plans call for an evolving habitat with construction beginning sometime around the year 2030. Mars City would consist of greenhouses, terrariums, and living areas within dozens — or even hundreds — of inflatable habitat modules. The settlement, completely self-sufficient, would derive its electricity from orbiting solar power satellites, with the power beamed down as microwaves to collector-antennas on the ground.

"If we want big habitats in the second half of the next century," says Ishikawa, "we must continue to build after the first landing. You must build on what you have; it's a long-term project.

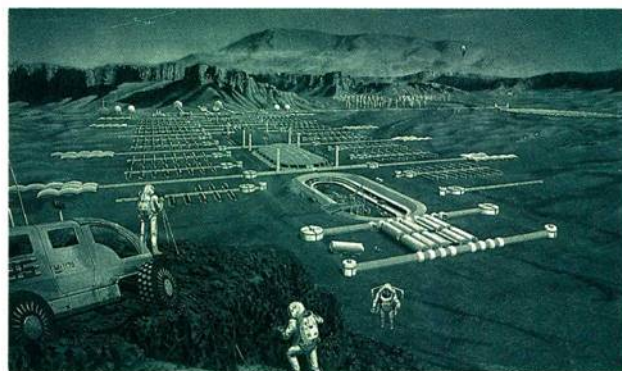
When you set up the first base, the final one must also be in your mind."

A more radical approach to Mars settlement was proposed by Michio Shimizu of the Shimizu Corporation. "We must understand the exploration of Mars from a financial approach, not academically," he says. "Sometimes the best way to build is the 'super-rush' approach."

Shimizu claims that the Japanese space organization NASDA could send Japanese astronauts to Mars as early as 1999, but by using Soviet launch vehicles the date could be as early as 1995 or 1996. "We don't need to wait for the anniversary of Columbus or the Moon landing," he remarks, referring to President Bush's Space Exploration Initiative, which calls for putting an American crew on Mars before the 50th anniversary of the first lunar landing.

But why should Japan undertake a Mars mission in the first place? "The main reason," argues Shimizu, "is national prestige. Japan must go to Mars to establish its strength in the eyes of the world. It's a matter of survival."

When asked about the possibility of cooperating with the United States, Shimizu expressed concern over NASA's



HABITATS SPRAWL ACROSS the Martian desert in a plan for settlement proposed by Japan's Ohbayashi Corporation.

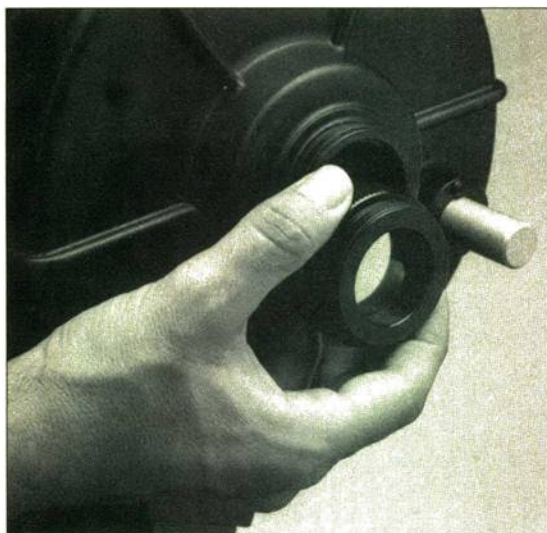
"fickle nature" regarding the Space Station. "The Shimizu Corporation and Mitsubishi want to build a module for the station, but NASA has postponed the project several times."

Ishikawa disagreed with Shimizu's evaluation of the role of international cooperation and the goals of Japan's Mars program. "The Japanese people are anxious to work with the U.S. as well as with the Soviets. They embrace international cooperation. Mars exploration is not simply a business venture. Science is a major motive for manned Mars missions."

Ishikawa adds, "Going to a new place, making a new home, this is what is exciting about going to Mars. I see a great deal of promise on Mars." — Michael Carroll

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Amateur News

Canadian Astronomers Celebrate Centennial

This year, Canada's astronomers celebrated the 100th anniversary of organized astronomy in Canada. In 1890, a group calling itself The Astronomical and Physical Society of Toronto held its first meeting. This astronomy organization, the first in Canada, later evolved into the Royal Astronomical Society of Canada, now with a nationwide membership of 3,500.

Over the Canada Day long weekend, June 29 to July 2, over 200 amateur and professional astronomers from across Canada converged on the country's capital city, Ottawa, for the annual General Assembly. Because it was the centennial year, the 1990 Assembly had a number of extra events on the program.

A special one-day symposium on Saturday focused on the theme "You and the Universe" and featured public lectures by Canadian science writers Terence Dickinson, Lydia Dotto, and Richard Jarrell. In another symposium lecture, astronomer René Racine outlined what he expects will be the hot research topics for the 90s. These include extraterrestrial life and intelligence, the composition of dark matter, the discovery of first generation Population III stars, determining the size of the universe, and solving the solar neutrino problem. The annual Helen Sawyer Hogg Lecture was given by Joseph Veverka, a regular contributor to the R.A.S.C.'s *Observer's Handbook* and Director of Cornell University's Spacecraft and Planetary Imaging Facility. Veverka presented a summary of the *Voyager* discoveries at Neptune.

In the paper sessions on Sunday, hot topics among the amateurs included CCD cameras, optical quality, light pollution, public education programs, and improving club newsletters.

On Monday, Lloyd Higgs, director of Canada's Dominion Radio Astrophysical Observatory and outgoing president of the R.A.S.C., gave the keynote lecture of the Assembly, a review of the astronomical research facilities proposed for Canada in the 1990s. The first to come on-line will be the Sudbury Neutrino Observatory currently under construction in a mine in northern Ontario. In optical astronomy, a twenty-five percent share in a proposed twin 8-meter



THE FUTURE OF CANADIAN ASTRONOMY was the topic of Lloyd Higgs' keynote talk at the 1990 R.A.S.C. General Assembly.

telescope project is Canada's highest priority for the 90s. Construction and operating costs, as well as observing time, would be shared with the United States and Great Britain, with the telescopes situated in Hawaii and in Chile.

But the four-day Assembly wasn't all talk. In fact, part of the activities included singing! The sixth annual General Assembly song contest got the audience singing along with astronomy songs like the Winnipeg Centre's "Virgo Cluster Blues." ("When you hunt them soft, dim fuzzies, sometimes you get confused. When you get lost in the Virgo Cluster, you get those Virgo Cluster blues.")

A "Murphy slide show" gave astro-photographers a chance to show off great and not-so-great photography results. Prizes went to the best and the worst of the show.

Although cloudy skies prevented much observing, people were able to tour the National Research Council's Ottawa River Solar Observatory and the host Ottawa Centre's Indian River Observatory (where Ottawa Centre members Rolf Meier and Doug George both discovered comets).

With its mix of serious talk and fun events, and with the participation of both amateur and professional astronomers, this year's centennial General Assembly showed that organized astronomy in Canada is as vital as ever. Next year's General Assembly will be in Vancouver, British Columbia. □

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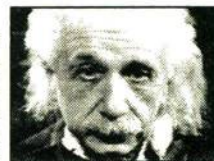
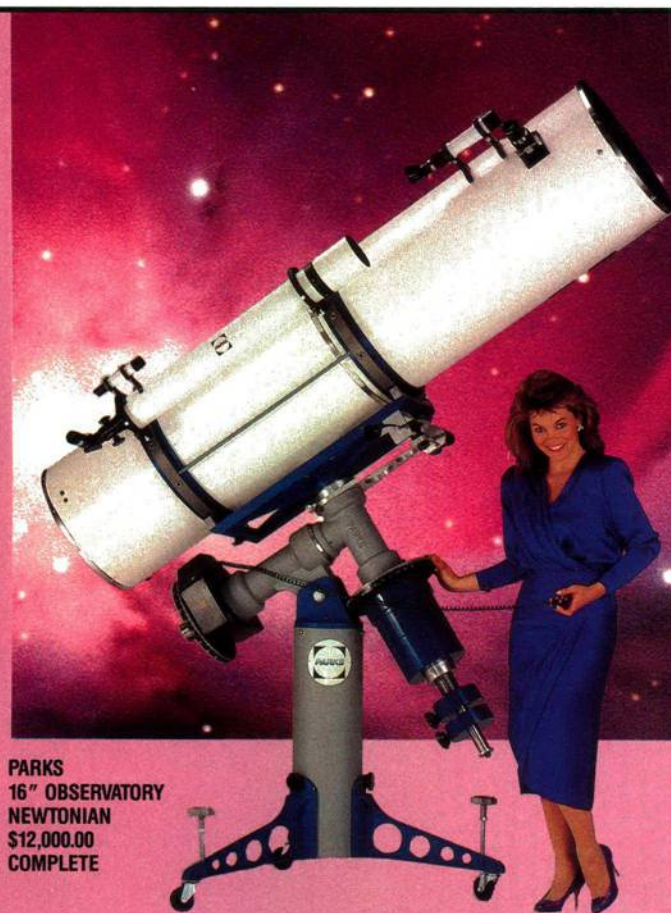


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STELLAR ASTRONOMY

The Largest Stars in the Galaxy

The dimensions of red supergiant stars are truly staggering. Some are large enough to engulf much of the solar system.

by James B. Kaler





Robert Eggert '70

RIVERS OF GAS STREAM off the red supergiant star VV Cephei and swirl around its small companion. This odd-ball pair of stars slowly dance about each other every 20 years. Painting by Robert Eggert.

No matter how long I study astronomy, the range of stellar sizes still amazes me. The smallest stars, the remnants of certain supernova explosions, are no bigger than a small city. The largest, some of which may produce supernovae, are nearly the size of the solar system. Some of the brightest stars in the Galaxy — and indeed in our sky — are members of this rare class of stars, the supergiants.

You can easily see two stars that dwarf the Sun. In the constellation Orion, two stars, Betelgeuse, which marks his right shoulder, and Rigel, at his left knee, outline this figure. This pair of supergiants displays a remarkable contrast immediately evident to the eye: Betelgeuse is orange-red, while Rigel is blue-white. Rigel has a surface temperature of some 14,000 K, while Betelgeuse is a cool 3400 K.

The common link between these two stars is their astonishing size and great intrinsic luminosity. This class of stars, the supergiants, is the most brilliant known, typically 10 to 15 magnitudes — 10,000 to one million times — brighter than our Sun.

But supergiant stars have more than just size and luminosity in common. They are also closely connected by the forces of stellar evolution that can cause the blue and red kinds to transform themselves from one to the other. Among the many stellar extremes in the Galaxy, the largest of all are the red supergiants.

The Mammoths of the Sky

Red supergiants are remarkably rare — only one for every million or so stars in the Galaxy. About 200 have been catalogued and studied. Nevertheless, they are so intrinsically luminous that several are visible to the naked eye. Two shine at first magnitude and, in a sense, define the winter and summer seasons for us. As the weather warms and Orion sets, Orion's mythological foe, Scorpius, rises. Marking the Scorpion's heart is a star whose red color inspired its very name, Antares, "the rival of Mars." It is indeed a strange coincidence that our two principal examples of red supergiants belong to antagonistic constellations on opposite sides of the sky.

To see what other red supergiants are visible to the naked eye, take a look at the map on page 34. Many of the stars may not be familiar to you. There are no red supergiants of second magnitude, and we must drop to third magnitude before we encounter Alpha (α) Herculis, also called Rasalgethi. There are two stars of fourth magnitude, Nu (ν) Persei and Mu (μ) Cephei. The latter is sometimes called "the Garnet Star" because of its reddish hue. Among the fainter members of this club, only the eclipsing binary VV Cephei is well known. Of the eleven naked-eye red supergiants, three — Mu and VV Cephei and HR 8164 — are grouped in one constellation, testimony to a close connection that we will explore below.

The spectral type of all these eleven red stars is class "M." The M stars are the coolest of all stars and have temperatures generally under 3900 K. (See "The Coolest Stars," May 1990.) At these low temperatures, the spectra of red supergiant stars are extraordinarily rich. They are dominated by the signature lines of elements that do not appear in the spectra of hotter stars.

For example, on page 36 is a tiny portion of the orange-red spectrum of Betelgeuse, a mere 35 Ångström spread from 6117 Å to 6152 Å. Here, we can see a forest of spectral lines, all created as the cool, neutral atoms in the star's outer layers absorb light. Lines of zirconium, iron, and vanadium are visible; there is one line of cobalt and even one of the rare earth element yttrium.

Yet despite their low temperatures, these red stars are very luminous. If any one of the eleven naked-eye super-

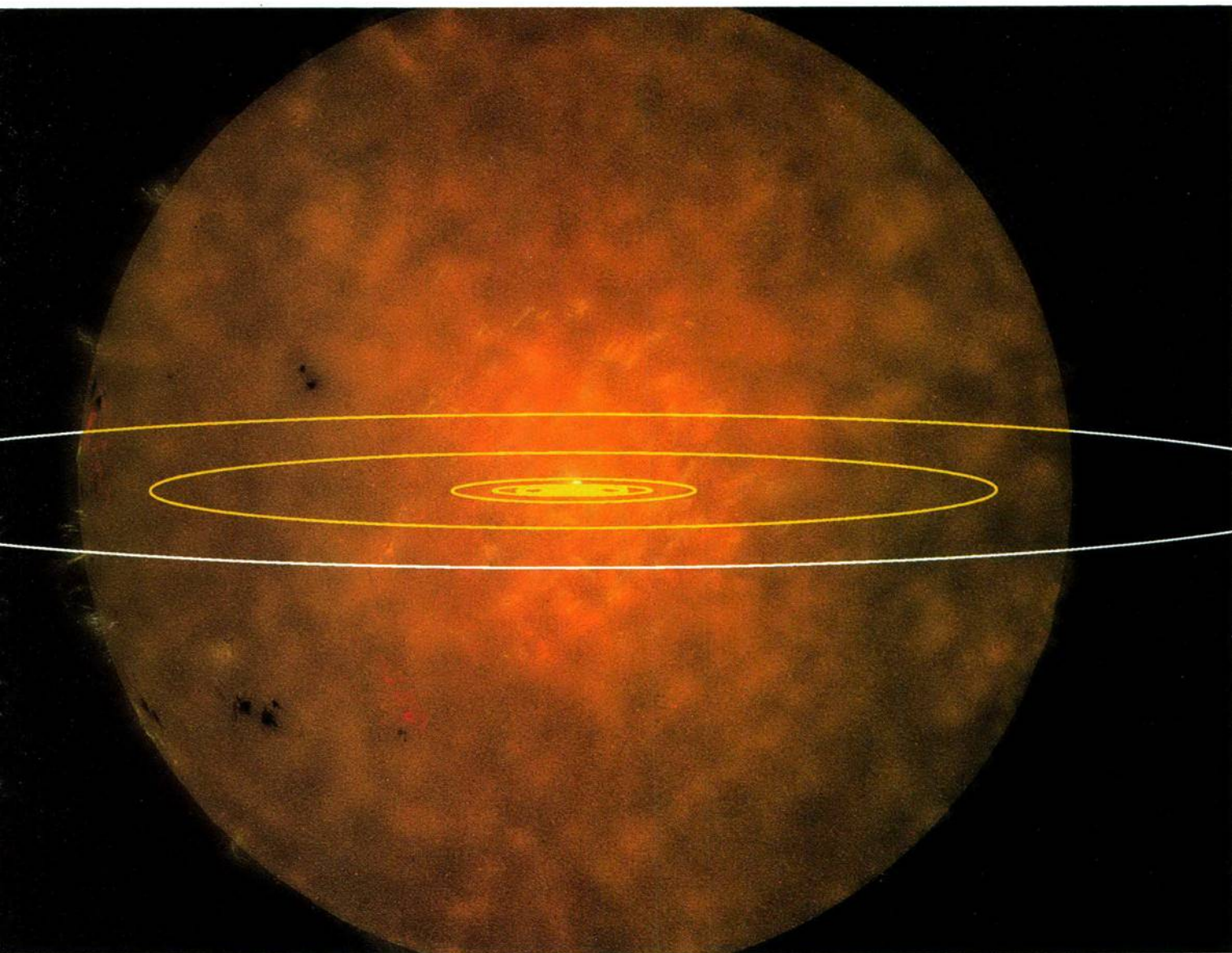
If VV Cephei were placed at the center of the solar system, it would extend out to the orbit of Saturn.

giants were as close as 10 parsecs, 32.6 light-years, it would be as bright as Venus.

The Sizes of the Supergiants

The dimensions of these stars are staggering. Astronomers have actually measured the angular diameters of four of the naked-eye supergiants — Betelgeuse, Antares, Alpha Herculis, and Mu Cephei. Betelgeuse is angularly the second largest star in the sky, 0.047 arcsecond across. It is exceeded only by the much closer giant, Mira. From its known distance of 620 light-years, we can easily calculate that the radius of Betelgeuse is about 900 times that of our Sun, or 4.5 astronomical units, nearly equal to the size of Jupiter's orbit. Antares has an angular diameter only somewhat smaller, 0.041 arcsecond. Since it is about 420 light-years away, this makes it roughly half the size of Betelgeuse, still far larger than the orbit of the asteroid Ceres. Alpha Herculis, with a diameter around 0.03 arcsecond and a distance of 500 light-years, is of comparable size.

How can we measure such a tiny diameter? After all, through a telescope, stars appear only as atmosphere-smearing points of light. At most observatories, the best atmospheric conditions permit resolutions of just under a second of arc, some 20 times larger than the dimensions



of the disks of supergiant stars. Astronomers can get around this limitation with ingenious techniques. The original idea, that of the Michelson interferometer, goes back to the early part of this century. The first device was a 10-foot steel beam placed across the top of the Mt. Wilson 100-inch telescope, on which two movable and two fixed mirrors were mounted. Parallel rays of light from a very distant star would bounce off the mirrors and combine at the focus to produce an interference pattern of light and dark fringes.

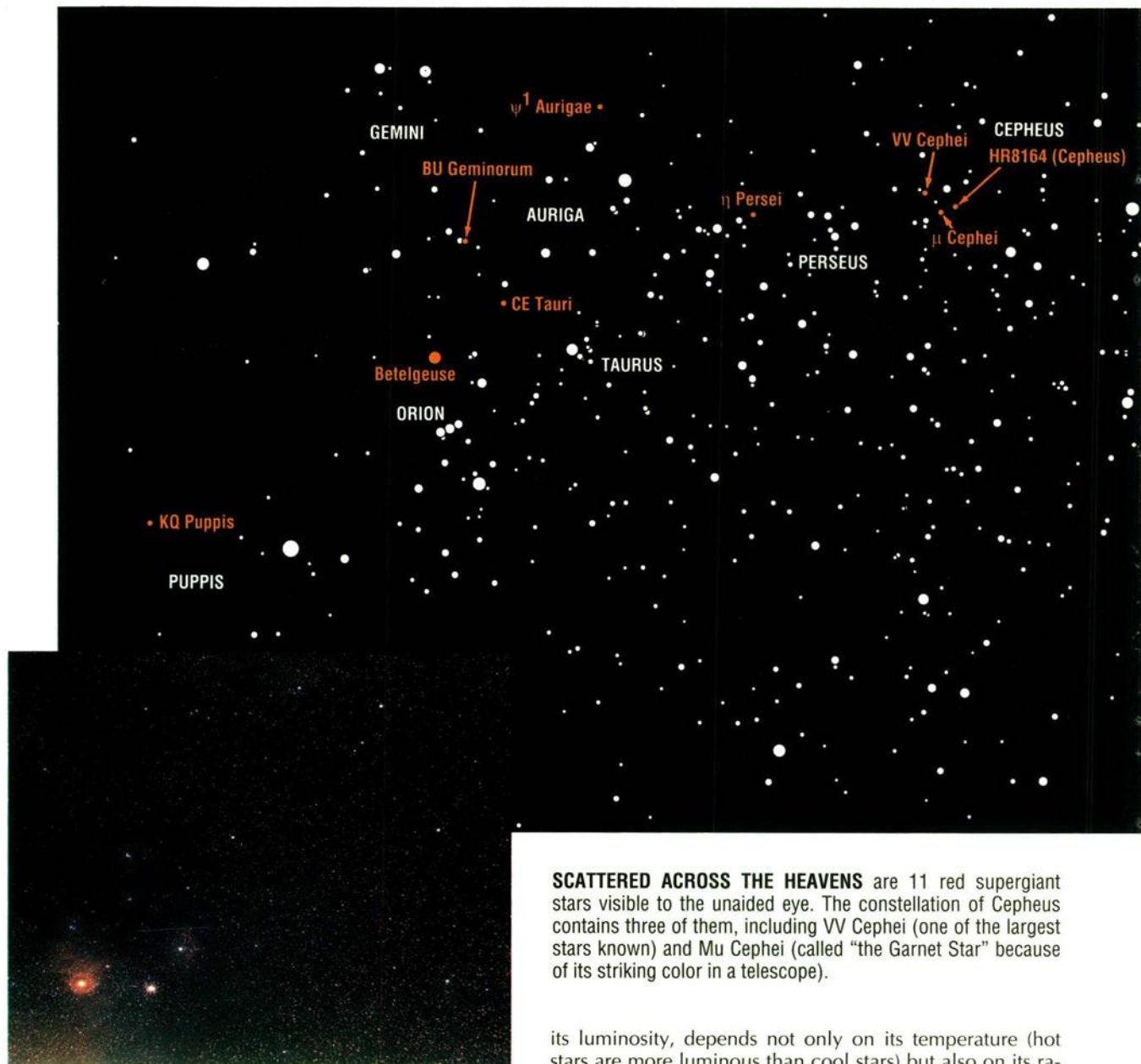
But a large nearby star with a significant disk contributes light from its entire surface. Light from opposite edges of the disk arrives at slightly different angles, and the fringe patterns are shifted relative to one another. It is possible to find a mirror separation at which the fringes overlap and disappear. The separation in turn gives us the stellar diameter. Using this technique, A. A. Michelson, J. A. Andersson, and F. G. Pease measured the angular sizes of Betelgeuse and Antares some 70 years ago.

Interferometry, as might be expected, has grown very sophisticated over the past few decades. For example, one technique employed in Australia uses two telescopes separated by nearly 330 feet; another at Mt. Wilson uses

plane mirrors up to 65 feet apart to send light down evacuated tubes. At Palomar Observatory, astronomers place a mask with several openings over the primary mirror, which produces the interfering effects of multiple mirrors. These devices are capable of measuring angular diameters to a few milliarcseconds, over ten times smaller than Michelson's pioneering instrument. Using the new Mt. Wilson experiment, for example, astronomers found that Mu Cephei has an angular size of a mere 0.0177 arcsecond, known to an astonishing precision of 0.0003 arcsecond.

Dancing Stars

The stars themselves sometimes provide the means for their own measurement. If two of them orbit one another, there is a chance that one will pass in front of the other to produce an eclipse. One of the most famous stars in the sky is Algol, or Beta (β) Persei. It dims by a full magnitude every 2.9 days as a small, bright, blue-white star hides behind a fainter yellow giant. VV Cephei is similar — except that the eclipse interval is 20.2 years! In this system, a brilliant blue-white star passes behind the red supergiant, dropping the brightness of the combined system by about half a magnitude. The duration of the



EMBEDDED IN A CLOUD OF NEBULOSITY in the constellation of Scorpius is one of the brightest red supergiants, the star Antares. Photo by Ronald Royer.

eclipse demonstrates the dramatic difference in size between the giants and supergiants. The Algol eclipse lasts but a few hours. (It is in fact a partial eclipse, but even if it were total, its duration would be under a day.) The white star of the VV Cephei system disappears for an amazing 1.2 years. We can determine the tilt of its orbit from a plot of the changing light and find its orbital speed from the Doppler shifts in the spectral lines. Combining these figures with the duration of the eclipse gives us an accurate measurement of the size of the supergiant — it has a radius 1,900 times the Sun's, or 9.4 AU, just smaller than the orbit of Saturn!

There are other ways to determine the sizes of these stars. Antares, Betelgeuse, and perhaps VV Cephei (its distance is quite uncertain) are not as intrinsically bright as Mu Cephei. The brightness of a star, or more correctly

SCATTERED ACROSS THE HEAVENS are 11 red supergiant stars visible to the unaided eye. The constellation of Cepheus contains three of them, including VV Cephei (one of the largest stars known) and Mu Cephei (called "the Garnet Star" because of its striking color in a telescope).

its luminosity, depends not only on its temperature (hot stars are more luminous than cool stars) but also on its radius. Large stars are brighter because they have more surface area emitting light. If we can measure the luminosity (or absolute magnitude) of a star as well as its temperature, we can then calculate its radius.

There is a complication. We measure the absolute visual magnitudes of stars using only the radiation the eye can see. However, cool stars produce much of their energy in the invisible infrared. We must therefore make a correction for the light we cannot see. For a typical red supergiant, this correction amounts to about 1.3 magnitudes, over a factor of three. Applying this "bolometric correction" to Mu Cephei, we find its bolometric magnitude — its absolute magnitude over all wavelengths of light — a very luminous -9.5 . Since it is a cool star, this means Mu Cephei must be enormous. Our calculations show Mu to have an astounding radius of 11 AU, even larger than the orbit of Saturn. In volume, Mu Cephei could contain 10 billion Suns.

We can check the calculations by adopting a distance of 2,700 light-years (taken from measurements of stars associated with Mu Cephei) and the measured angular diameter of 0.0177 second of arc. This gives a radius

***We see only one red
supergiant for every million or
so stars in the Galaxy.***



ORION THE HUNTER is marked by two supergiant stars, the blue-white star, Rigel, at lower right, and the monstrous red star, Betelgeuse, at upper left. Photo by Mark Coco.

of 7.4 AU. The discrepancy is caused by uncertainties in the distance, temperature, and bolometric correction.

The immensity of stars like VV and Mu Cephei is hard to comprehend. We take pride in sending a spacecraft from Earth to Saturn, a journey that took several years. Yet the entire trip could all fit inside a single star.

How the Supergiants Lose Weight

Red supergiants are so distended that they can be unstable and pulsate erratically. The alpha star of Orion, Betelgeuse, is usually about 0.4 magnitude fainter than the beta star, Rigel. Betelgeuse also displays rapid variations on a scale of days, weeks, and months, as well as a slow, six-year periodicity that changes its brightness by nearly a full magnitude, allowing it sometimes to rival Rigel.

Of the eleven naked-eye red supergiants, nine are variable, and four carry classical variable star names. Mu Cephei, Alpha Herculis, and CE Tauri are semi-regulars. Alpha Herculis changes by about a magnitude over roughly a 6-year period and exhibits short-term fluctuations as well. Mu Cephei displays larger variations of a magnitude and a half over two or three years along with a 13-year oscillation. The other variable red supergiants are classified simply as "irregular," with no predictable period in their brightness fluctuations.

Red supergiants are variables in part because gravity at a supergiant's surface is only one ten-thousandth as strong as that at the Sun's surface. With the enormous energy output of these stars — up to a million times the Sun's — it is no surprise that they are losing mass. This loss is almost certainly related to variability, but in ways that are still unclear.

A good example of a star that is shedding its outer layers is Alpha Herculis. It has a 5th-magnitude companion star at an angular separation of 5 arcseconds, easy to split in a small telescope. The secondary itself is a spectroscopic binary (unresolvable by eye) that consists of a yellow giant and a yellow-white dwarf. As these two orbit one another every 52 days, their spectral lines move back and forth as a result of constantly changing Doppler shifts. Some of the lines, however, do not exhibit Doppler shifts — they are stationary and are also seen in the spectrum of Alpha Herculis itself.

The explanation is that the supergiant, thought to be about 15 times the mass of the Sun, has lost so much matter that an expanding gas cloud now envelops both it and its binary companion. This material extends at least 700 AU away from Alpha Herculis, 17 times the radius of our solar system. This material appears to be flowing from Alpha Herculis at a rate of about 1 millionth of a solar mass per year. This sounds like a small amount, but over the course of millions of years it adds up.

Everywhere we look we see other evidence for mass loss from supergiants. Antares has a companion star and a cloud comparable to the one surrounding Alpha Herculis. However, the secondary star orbiting Antares is hot enough to ionize the stellar wind and trigger it into luminescence. As a result, we can actually see a small nebula around this red supergiant. Because Antares is larger and much more luminous than Alpha Herculis, its mass loss rate is some 50 times greater.

VV Cephei is stranger still. Anomalous lines in its spectrum indicate gas streaming from the great supergiant

The inner star may orbit Betelgeuse in only two years and actually appears to be inside the supergiant's chromosphere.

toward its companion star. In this case, the stream wraps itself into a disk around the smaller, hotter star. What a dazzling display it must be up close, as a tiny blue-white point and the red behemoth dance about one another.

A Close-Up of Betelgeuse

The best observed of all these red supergiants, however, is our old friend Betelgeuse or Alpha (α) Orionis. We know a remarkable amount about the structure of the enormous and complex system that surrounds it.

At right is a recent image of Betelgeuse obtained through stellar interferometry. At the center of the figure is the disk of Alpha Orionis itself, here 0.035 arcsecond across. This is smaller than the older estimates mentioned earlier. Possibly it is in a temporarily contracted state associated with its variability, or the earlier measurements were confused by matter surrounding the star, demonstrating the uncertainties involved.

Here the star is "only" 3.3 AU in radius. There is no detail visible on the surface — the resolution is not quite good enough. But the reconstruction of the interferometry data clearly shows a partial ring of dust at 2.5 stellar radii ($2.5 R_*$) away from the center of Betelgeuse. This puts the dust actually *inside* the cool chromosphere of the star. (In the Sun, the chromosphere is a thin layer of cool red gas separating the visible photosphere from the surrounding corona.)

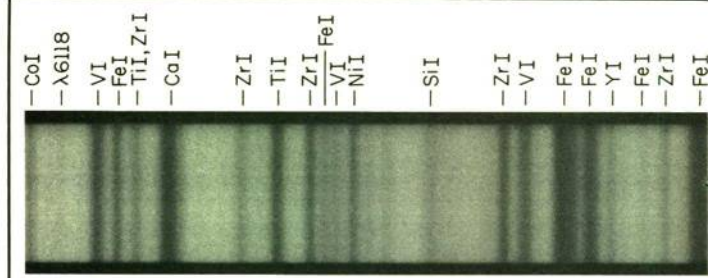
That is only the start. Observations by a different type of infrared interferometer show a ring of dust between 12 and 125 stellar radii with a peak near $45 R_*$. But we know the dust extends even farther out than that. Astronomers have seen blue polarized light scattering off dust grains up to 90 arcseconds away from the star — that works out to 17,000 AU from Betelgeuse, or 5,000 times the stellar radius. This disk is large enough that if your eyes were sufficiently sensitive, you could actually see this great system with your naked eye.

The interferometry observations also reveal the likelihood of two close stellar companions — one (perhaps at third magnitude) 25 stellar radii away, another at only 2 stellar radii or so. The inner star may orbit the supergiant in only two years and actually appears to be inside its chromosphere. It may be responsible for producing the distorted half-moon shape of the inner dust cloud. We have only begun to explore this remarkable system.

The Fate of the Giants

Remember the curious concentration of naked-eye red supergiants found in Cepheus? This gathering is no mere coincidence. Stars tend to form in groups out of large molecular clouds. The most massive stars to form from such clouds become what we call type O and B stars — blue-white stars with surface temperatures of 15,000 to 40,000 K. These hot stars contain the equivalent mass of at least ten of our Suns.

The O and B stars, however, do not live very long. The hotter they are and the greater their mass, the more rapidly they burn their fuel. A normal lifetime for one of these squanderers may be no more than 100 million years (for a 15 solar-mass star) or even as short as 7 million years (for a 30 solar-mass star). This is far shorter

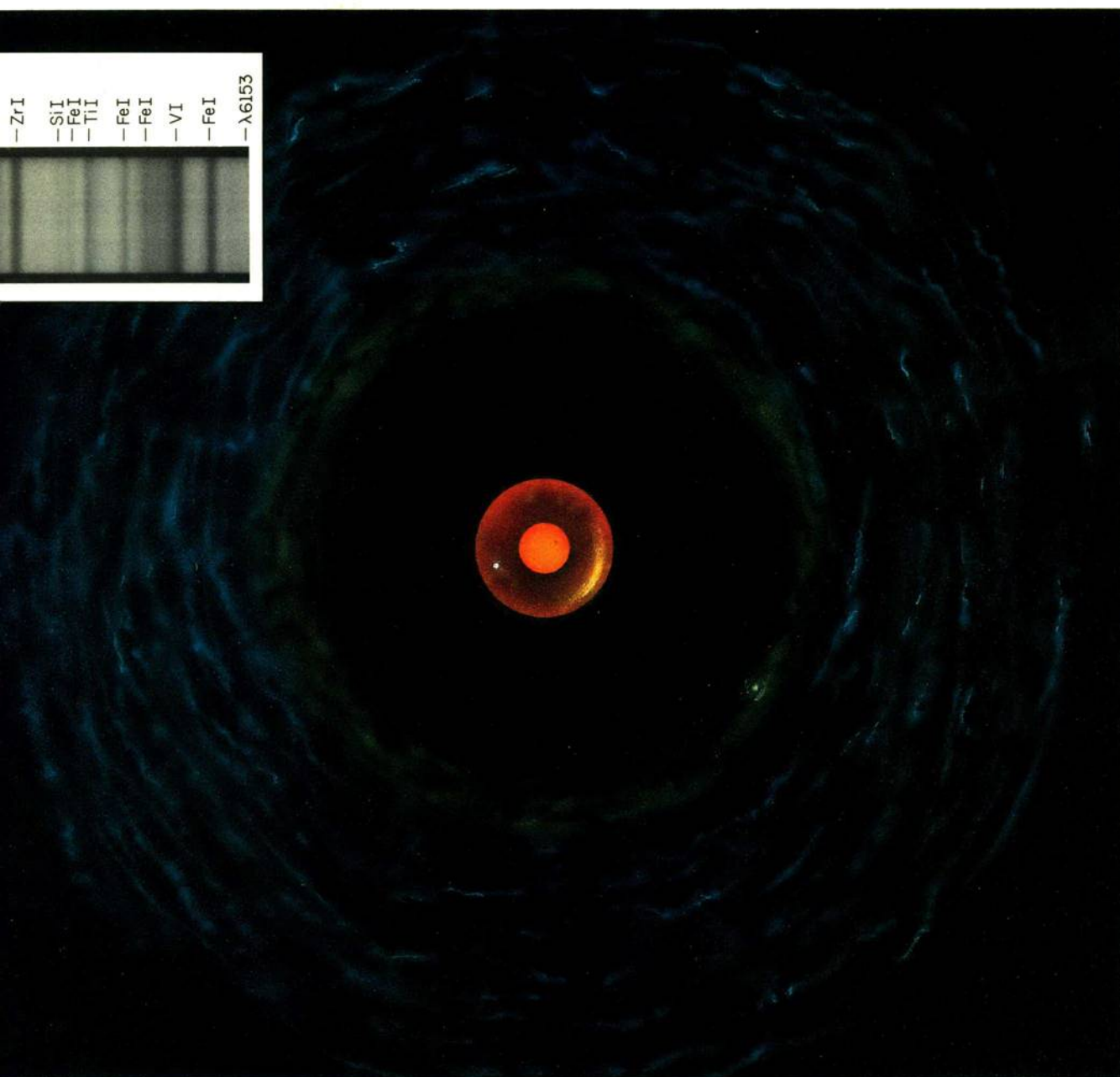


THE DISK OF BETELGEUSE (above) has been reconstructed from observations with an optical interferometer. The resolution is insufficient to see surface detail but shows an arc of dust on one side of the star. A small section of the red end of Betelgeuse's spectrum (top) shows an intricate structure of spectral lines, which indicates a rich mix of elements and molecules. The complex system that surrounds Betelgeuse (right) seems to consist of two companion stars and several rings and arcs of dust and gas.

than the 10-billion-year life expectancy for stars of average mass like our Sun.

The O and B stars evolve so quickly that they can never move very far from their places of birth during their lifetimes. Even when they are not formed in small gravitationally bound clusters, we still find them in association with one another. These OB associations abound in space and are named after their parent constellations. Scattered amid the OB associations are red supergiants — they are what O and B stars turn into when they age.

In fact, once hot O and B stars start to turn into red supergiants, they go with remarkable speed. A 30 solar-mass star starts the final chapter in its life as spectral type O3. Then it first expands and cools a bit to become a blue type B star. As it exhausts its hydrogen fuel, changes in its interior trigger a transformation from a blue giant to a yellow supergiant in only a few hundred thousand years. Stars don't linger long at this stage; hence yellow supergiants are very rare. The pace of evolution slows after this point. As the aging stars cool and grow some more they shed a great deal of their mass. The numbers are un-



certain, but what began life as a 30 solar mass star may, by the time it reaches the red supergiant stage, be reduced by half. Eventually the evolving stars settle in as red supergiants. They pile up at the cool end of the temperature scale, giving us a number of these monster red stars even in the naked-eye sky.

This explains the collection of naked-eye red supergiants in Cepheus. All three, Mu, VV, and HR 8164 belong to a well-known association called Cepheus OB2, some 2,700 light-years away. They are the brightest examples of stars that have quickly evolved to the final stages in their lives and have not yet dispersed from the sites of their births.

What happens when a red supergiant dies? Some may consume all their available fuel and develop cores of inert iron. They are then unable to support themselves. Their outer layers collapse upon the core, creating a catastrophic explosion — a supernova. They shed 90 percent of their mass in literally an instant, with the remnant core shrinking into a neutron star or black hole. But at what point this event happens remains unclear. A supernova

candidate may first evolve back into a blue supergiant before exploding.

On the other hand, some red supergiants seem to avoid the explosive fate of a supernova and instead transform into one of the Galaxy's stranger denizens, the bizarre Wolf-Rayet stars. These are stellar remnants that have lost all of their outer hydrogen envelopes and exhibit a rich composition of carbon and nitrogen, the results of eons of nuclear burning. We'll explore these odd members of the stellar family in our next look at the sky's most unusual stars. □

James B. Kaler is a professor of astronomy at the University of Illinois, Urbana-Champaign. Previous articles in this series were "Realm of the Hottest Stars," February 1990, and "The Coolest Stars," May 1990. A version of this article appeared earlier in the Italian astronomy magazine, l'Astronomia. Professor Kaler's articles on stellar superlatives will also be published in book format by Cambridge University Press.



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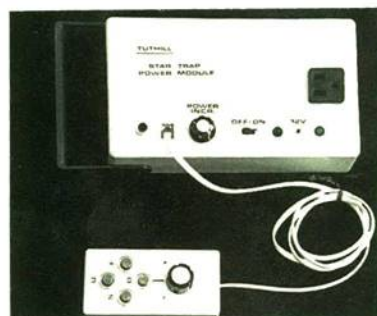
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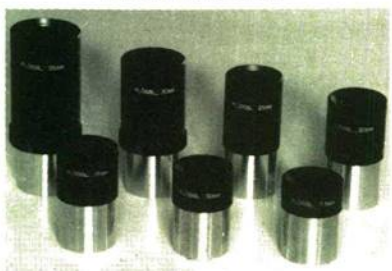
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Strange Doings at the Milky Way's Core

New high-resolution radio images of the Galaxy's central arcsecond show swirling clouds of gas, each hundreds or thousands of times bigger than the solar system. Nearby, a red supergiant star is being eroded by a ferocious wind from the Galactic center.

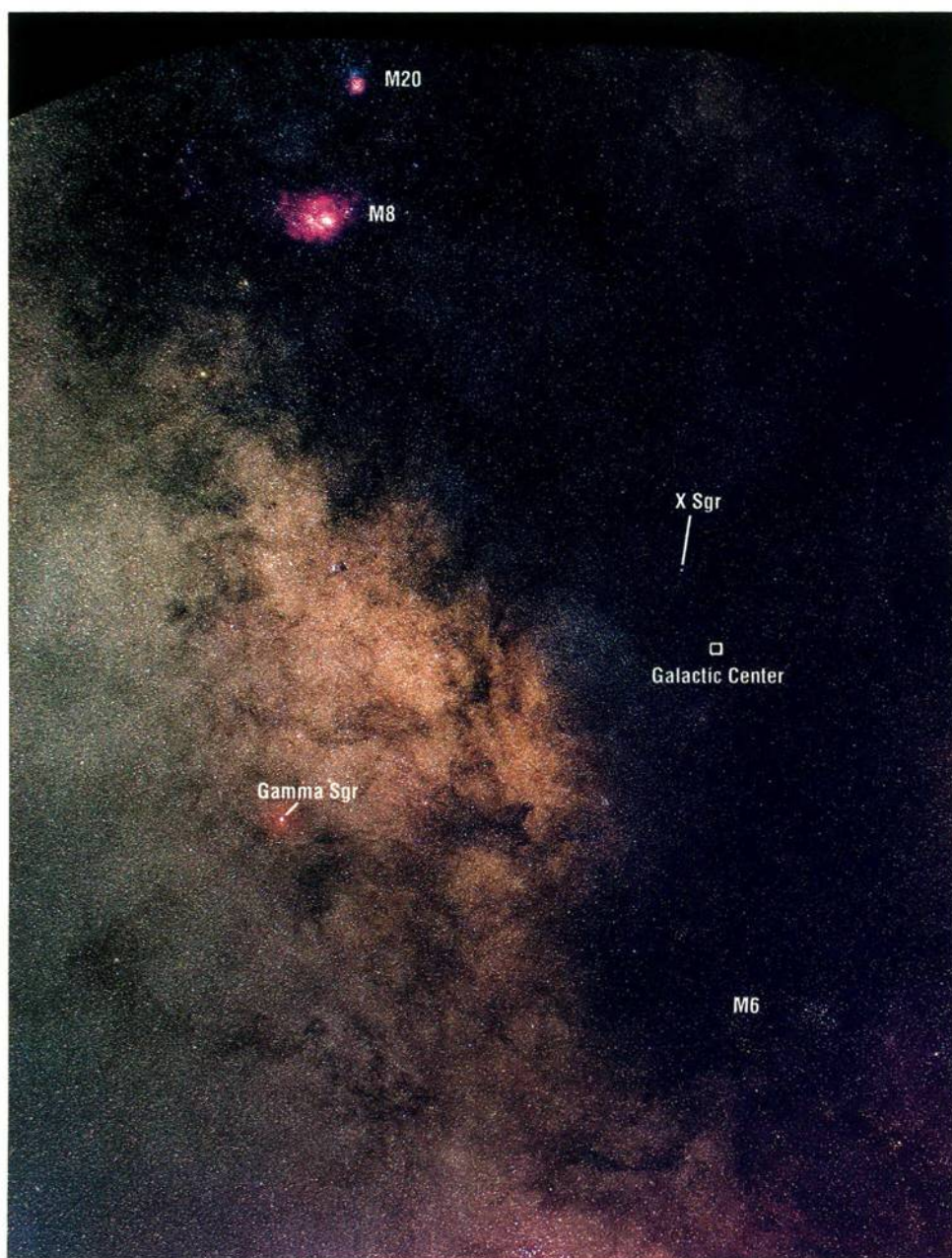
by Robert Burnham

On moonless evenings early this month Sagittarius lies in the southwest. The Milky Way there looks like silver steam rising from the spout of Sagittarius' Teapot asterism, and the stars seem to shine especially bright through the cool evening air. About one palm-width to the right of Gamma Sagittarii, the star at the tip of the Teapot's spout, lies a 5th-magnitude star, X Sagittarii. If you look one finger-width below X Sgr, you will be gazing straight toward the heart of the Milky Way Galaxy. But the Galactic center lies 28,000 light-years away and only radio waves can penetrate the clouds of dust and gas that obscure our view of it.

Three astronomers, Farhad Yusef-Zadeh of Northwestern University, Mark Morris of UCLA, and Ronald Ekers of the Australia Telescope, have used the 27-antenna Very Large Array radio telescope to make highly detailed images of the Galactic center. In particular they focused on the radio source known as Sagittarius A* (pronounced "ay-star"). Sgr A* is not the only radio source close to the center of the Milky Way, but it is the strongest and most compact. Moreover, it appears to dominate large-scale movements, at least locally: gas clouds lying east of it are receding from us, while those to the west are approaching.

These pictures take you from the Sagittarius star clouds all the way in to the plasma clouds flanking Sgr A*. The detail of these images is breathtaking: photo #5 spans just over 1 second of arc. If the solar system were taken to the center of the Galaxy and dropped into the image, its 100 AU diameter (twice Pluto's maximum distance from the Sun) would be as large as the yellow dot.

What, exactly, does lie at the center? Although the actual core object has not been resolved, astronomers



MAGNIFICENT STAR CLOUDS line the Milky Way in Sagittarius, but thousands of light-years deeper into space lies the core of the Galaxy. Photo by Ronald Royer.

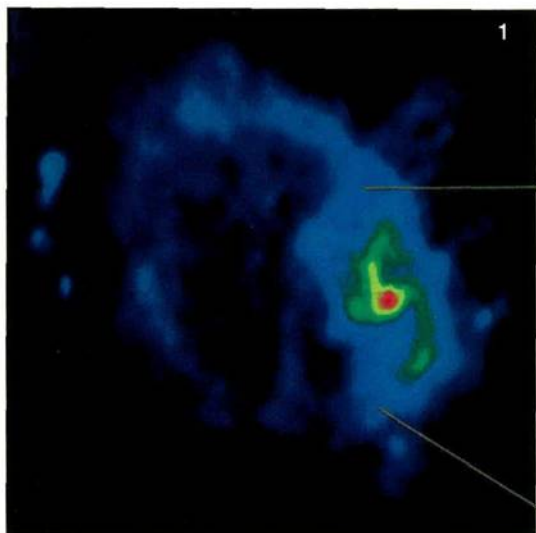


PHOTO #1: Spanning about 5 arcminutes, this giant shell of gas may be a supernova remnant behind the Galactic core, which lies in the "hot spot" at right.

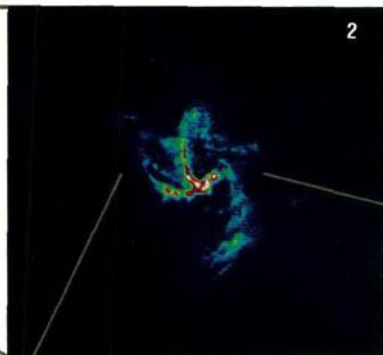
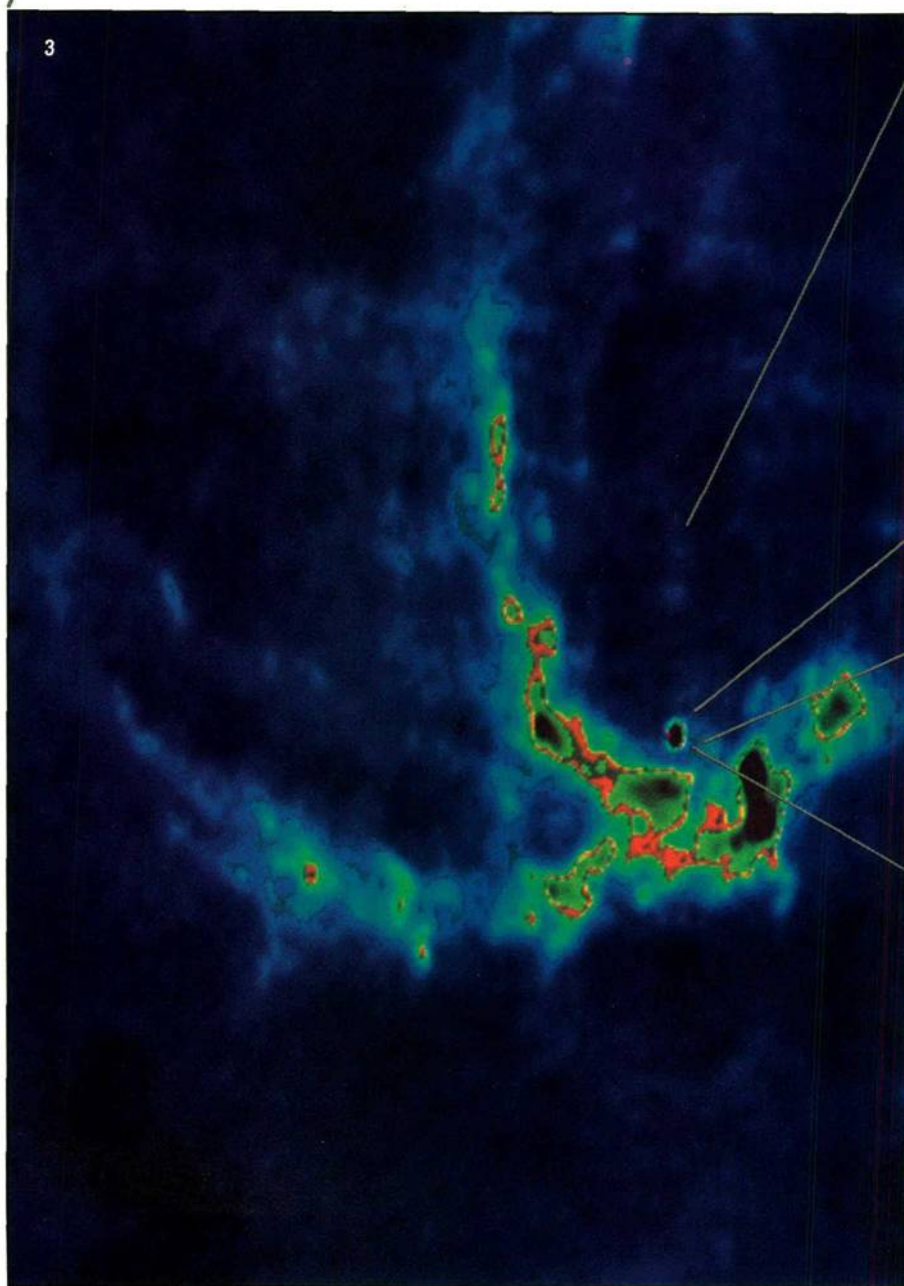


PHOTO #2: The pinwheel structure is about one arcminute across and consists primarily of ionized gas.

PHOTO #3: Enlarged, the pinwheel shows many knots and bright regions. Sagittarius A* marks the source believed to be the Galactic core.



suspect that it is a black hole. Estimates of its mass range from as low as 500 times that of the Sun up to 5 million times. Assuming it exists, the black hole would be surrounded by a sheet of material called an accretion disk, made up of dismembered stars, clouds of gas, and hot dust particles. Material drawn into the black hole would be heated to very high temperatures before it disappeared, thus keeping the accretion disk and vicinity bathed in high-energy radiation. On local scales this radiation ionizes gas clouds, turning them into radio-visible plasma. At a couple of light-years' distance, this "core wind" (plus strong ultraviolet radiation) is eroding a red supergiant star called IRS 7. It is the comet-like object in photo #4.

A tantalizing question concerns the three-dimensional structure of the features. Which lie in the foreground? Which are distant? The observations here draw a simple two-dimensional map of the features. New observations have measured the radial velocities (speed directly toward us or away) of each object in the photos, but it will take time to process the raw data into answers. An exciting possibility is that the black hole's gravity should be strong enough that any objects lying near-by will be moving quickly. In fact, Yusef-Zadeh, Morris, and Ekers calculate that a similar radio picture taken as soon as 10 years from now would show that the clouds have shifted position.

The core of the Milky Way has long been a mystery, and it retains much mystery still. But the innermost regions of the Galaxy are gradually becoming visible, and accurate maps are finally replacing cloudy speculations. □

4

PHOTO #4: IRS 7 is a red supergiant star being blasted by a high-velocity "wind" of particles from Sagittarius A*.

IRS 7

Sgr A* (unresolved)

PHOTO #5: The Galaxy's innermost arcsecond shows Sgr A* flanked by four symmetrically-placed clouds of ionized gas. The size of the solar system is shown to scale.

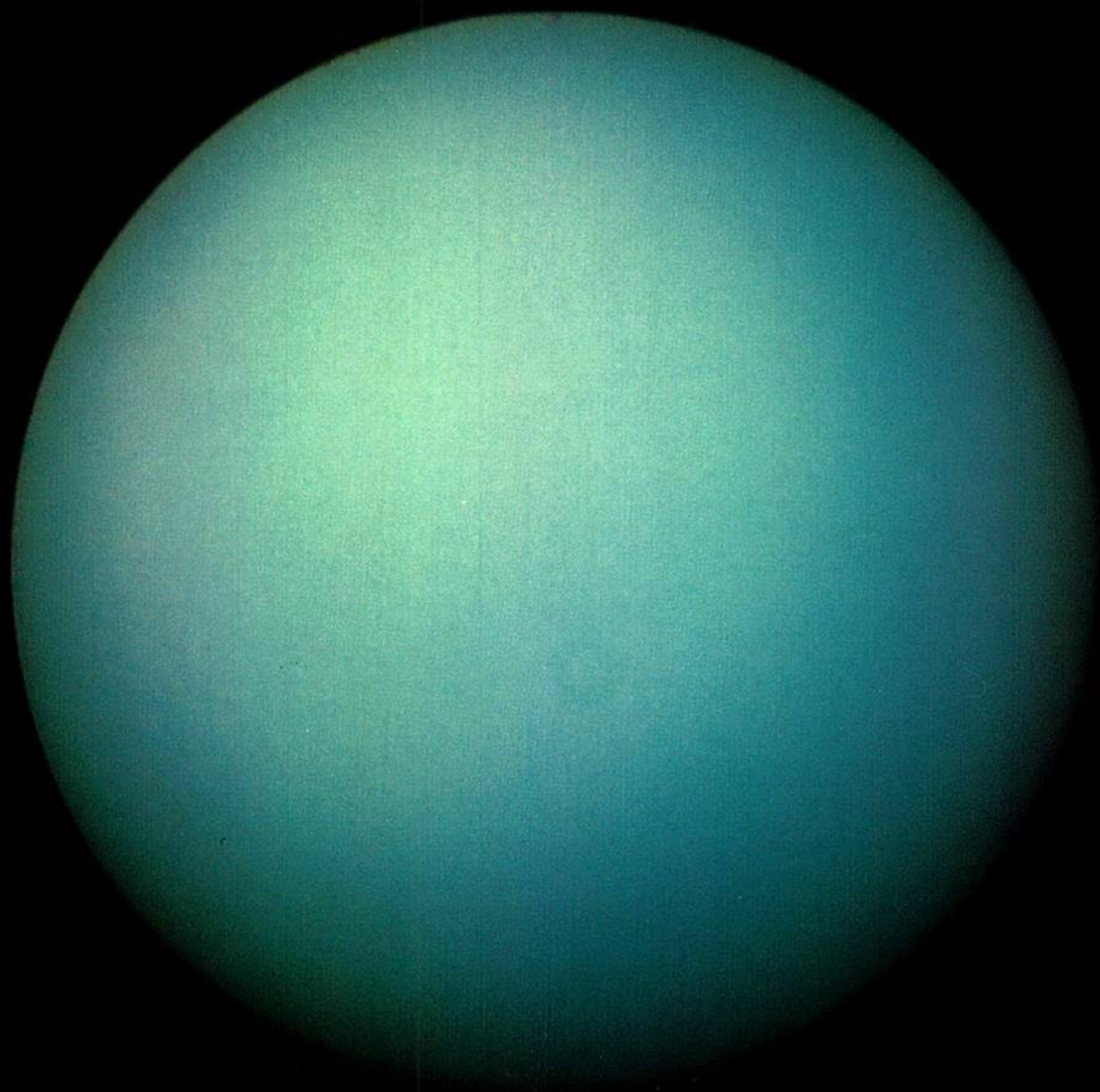
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Ionized clouds

Sgr A*

Solar system
(if placed at the Galactic center)

Ionized Cloud



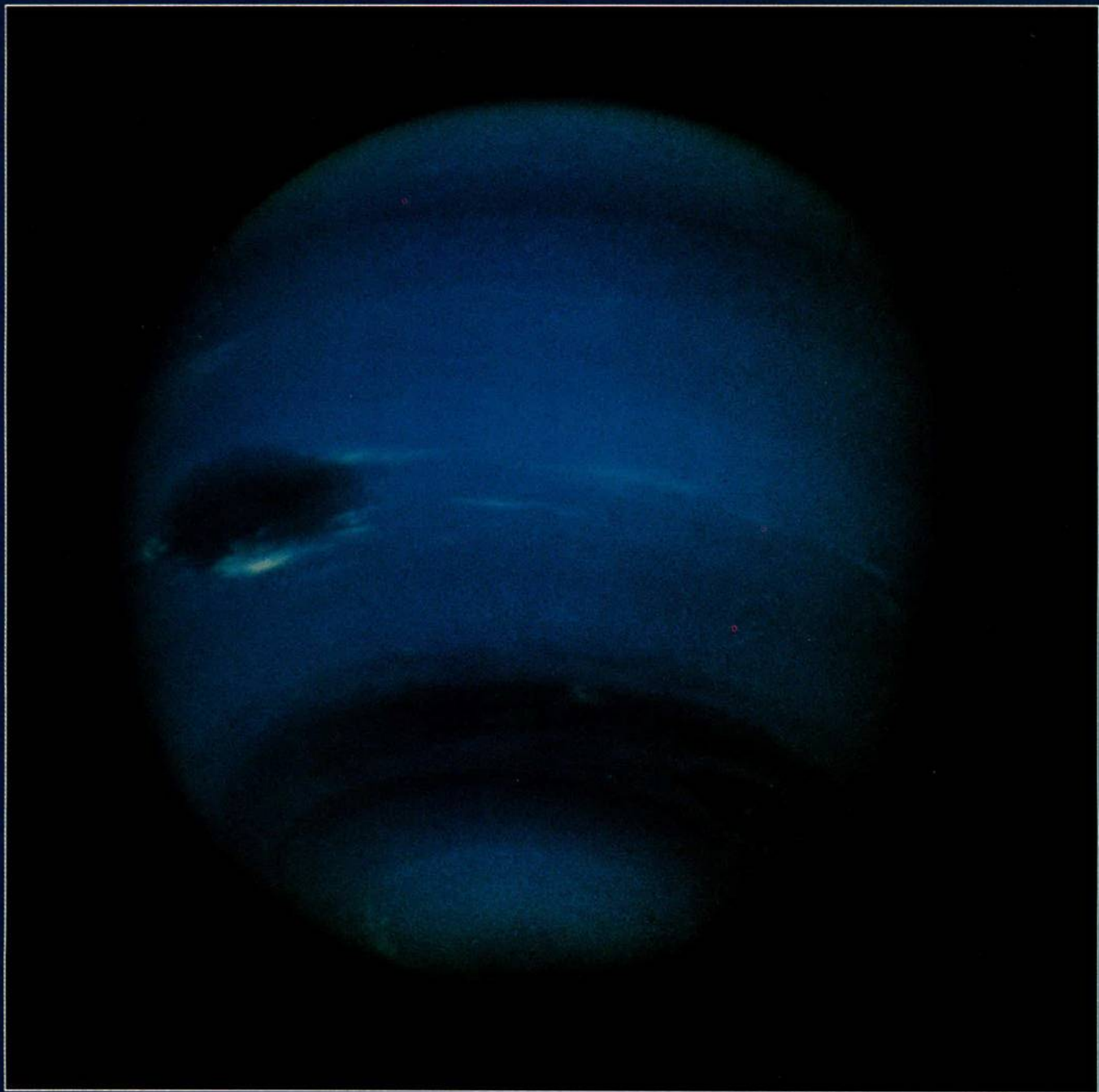
PLANETARY FRONTIERS

Big, Blue:

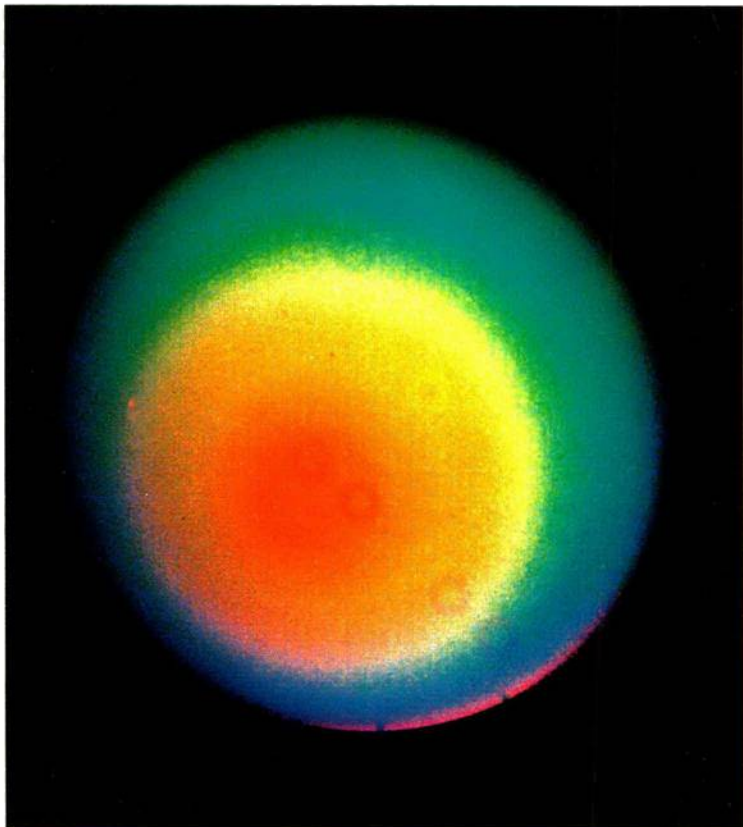
The Twin Worlds
of Uranus and
Neptune

Voyager's last two ports of call provided scientists with an intriguing look at a pair of planets more closely matched than any in the solar system.

by Timothy Dowling



TWO STUDIES IN BLUE that surprised planetary scientists: Uranus (left) and Neptune. Expected to show Saturn-like cloud details, Uranus turned out to be extremely bland. But more distant Neptune, predicted to be featureless, displayed a startling wealth of detail.



If you could take any trip you like, one of the most exciting and unearthly would be to hitch a ride on a comet and follow it into the outer solar system. Bathed in an icy twilight from a pinpoint Sun, this distant realm is where comets like Halley quietly turn around and retake aim at the Sun. It is also the domain of the twin gas-giant planets, Uranus and Neptune. Now that *Voyager* has performed its reconnaissance of them and we have all the close-up data we can expect for many decades, the time has come to begin putting what we've learned into some kind of order.

Big Blue Globes

Photos of Uranus and Neptune show that both are blue-green and practically the same size, intermediate between Earth and Jupiter. They differ in volume by only 12 percent — less than what separates the Sun's other "twin" planets, Earth and Venus. The blue color of both is undeniably beautiful, but as inhabitants of Earth, familiar with blue sky and water, we may have a natural bias for blue planets. Uranus and Neptune, however, are blue for a different reason than Earth: the methane in their atmospheres absorbs reddish light.

Like all gas-giant planets, Uranus and Neptune have banded atmospheres. Significantly, their atmospheric bands align with the planets' rotation axes rather than the points of greatest solar heating. This says that rotation dominates the flow of gases in their atmospheres and not solar heat. But the distant Sun still has its effects. Uranus and Neptune both have well-developed smog layers in their stratospheres; particularly smoggy is the sunlit pole of Uranus. Smog results when ultraviolet sunlight turns the indigenous

A THICK, SMOGGY HOOD caps the sunlit pole of Uranus in this color-enhanced view. The reddish smog results from the breakdown of methane by ultraviolet light. (The dark "doughnuts" are shadows of dust in the camera optics.)

methane into substances like ethane, acetylene, and diacetylene.

But smog apart, Uranus is almost spooky in its bland featurelessness. It is also remarkable as the only giant planet lacking a large internal heat source. With Jupiter, Saturn, and Neptune, at least 40 percent of the heat emitted comes welling up from inside the planet, but at most only 6 percent of Uranus' heat is internal. This produces the curious fact that Uranus and Neptune have almost identical effective temperatures (about 59 K), despite Neptune's being 50 percent farther from the Sun. Why Uranus should have so little internal heat is unknown, but it may result from the violent shakeup that Uranus is thought to have suffered when its rotation axis was tipped 98°.

The atmospheres of Uranus and Neptune are similar in how their temperatures vary with latitude — or, rather, *don't* vary. On Earth the atmosphere at the equator is many tens of degrees warmer than at the poles. But *Voyager* saw no big temperature differences on Uranus or Neptune, only a small one: the mid-latitude regions in each hemisphere are 2 K cooler than the rest of the atmosphere. Why? Once again no one knows, and scientists can only guess that the mid-latitudes may be regions where gas is rising and cooling as its density drops.

Cloud features are rare in Uranus' atmosphere, with two elongated bright features (at 27° and 35° south latitudes) being virtually the only ones visible. In contrast, Neptune has many clouds and oval storm systems. Neptune's closest equivalent to Uranus' two bright cloud features is the Scooter, so-named because it moves quickly relative to the larger features. The Scooter was seen first at 42° south latitude, where it stayed for three weeks before drifting northward to 40° south. It is composed of many east/west streaks stacked in latitude whose number and length vary from day to day. This causes the Scooter's overall shape to change from round to square to triangular. Astronomers think the Scooter is not a true storm system but rather a kind of variable packet of atmospheric waves.

The dominant storm system on Neptune is the Great Dark Spot. This oval feature is remarkably similar to Jupiter's Great Red Spot. The Dark Spot spans 38° in longitude and 15° in latitude (compared to the Red Spot's 30° by 20°). The Great Dark Spot is an anticyclone (rotating counterclockwise in the southern hemisphere) and is thus a high-pressure storm just like the Red Spot. But unlike the Jovian feature, the Dark Spot stretches and contracts with an 8-day period. During the *Voyager* encounter it also drifted steadily northward at about 0.1° per day. Storm systems on Neptune are more loosely confined in latitude and in shape than similar storm systems on Jupiter or Saturn, probably because Jovian and Saturnian storms are hemmed in by much narrower jet streams.

A white feature called the Bright Companion was associated with the Dark Spot. Like the Scooter, the Companion shows a linear east/west structure. Simultaneous ground-based and *Voyager* images confirm that the Bright Companion is one of the few clouds on



NEPTUNIAN WHIRLYGIGS: the storm called D2 (above) has a bright core of high-rising cloud that may resemble a thunderstorm. The Great Dark Spot (right) — eerily reminiscent of Jupiter's Red Spot — even mimics its size and movements.



Neptune visible from Earth. It is created when a huge, high-pressure storm system such as the Dark Spot affects the local winds the way a mountain does, forcing them to rise into cooler altitudes, where vapor condenses and clouds form.

Another Neptunian storm, dubbed D2, was seen at 55° south latitude. Several weeks after discovery, D2 developed a bright core that persisted for the rest of the encounter. The bright material rose high into the atmosphere and might have looked something like a terrestrial thunderstorm if seen from the side. Astronomers think such vertical motions could be an important way to carry trace gases from the lower atmosphere into the upper.

D2 also migrated in latitude. First seen at 55° south, it moved northward to 51° south and then returned to 55°. As *Voyager* flew past, it was starting another trek northward. D2 drifted across a latitude where the cloudtop wind speed is the same as the deep interior's rotation speed. Past experience has taught planetary astronomers to expect a vortex or a storm at such "zero-speed" locations. The Great Dark Spot, however, may be a significant counterexample, being the only major storm that lies well away from a zero-speed latitude. Even Jupiter's Great Red Spot, so similar in many other ways, lies near a latitude where the wind speed matches the rotation.

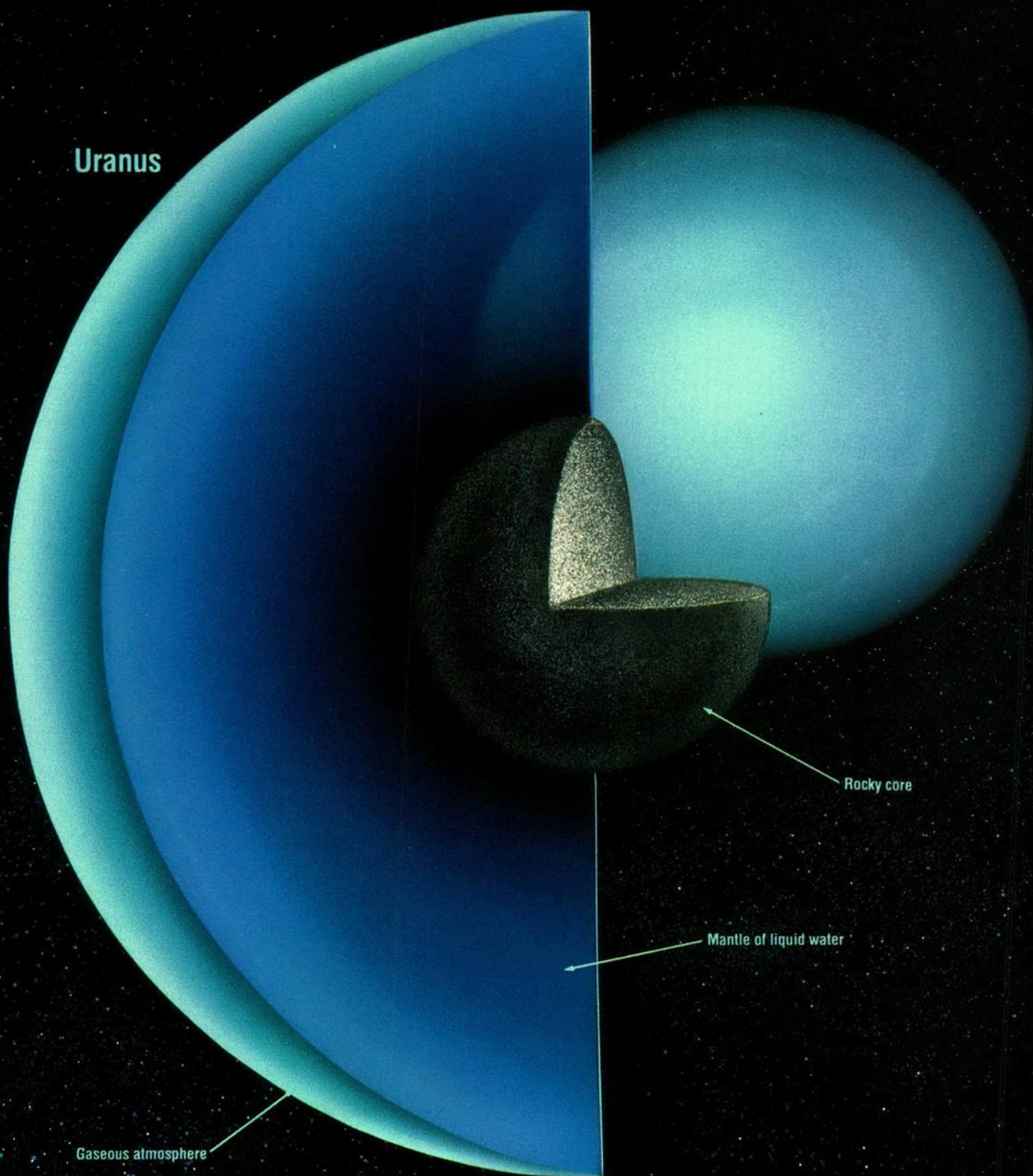
Astronomers studying atmospheric motions are now seeking answers to many questions, such as why Jupiter's Red Spot and Neptune's Dark Spot have nearly the same angular size and occur at nearly the same latitude, what forces drive them, and why Uranus is the only giant planet *without* oval storm systems.



THE SCOOTER speeds along relative to neighboring features. A variable array of linear clouds, the Scooter can appear to be square, triangular, or circular.



THE DARK 'DOT' that lies within 1° of Neptune's south pole puzzles scientists by its very existence. Solar heating is at a minimum there, while Coriolis force, which should have eradicated the dot, is at a maximum.



TWINS UNDER THE SURFACE?

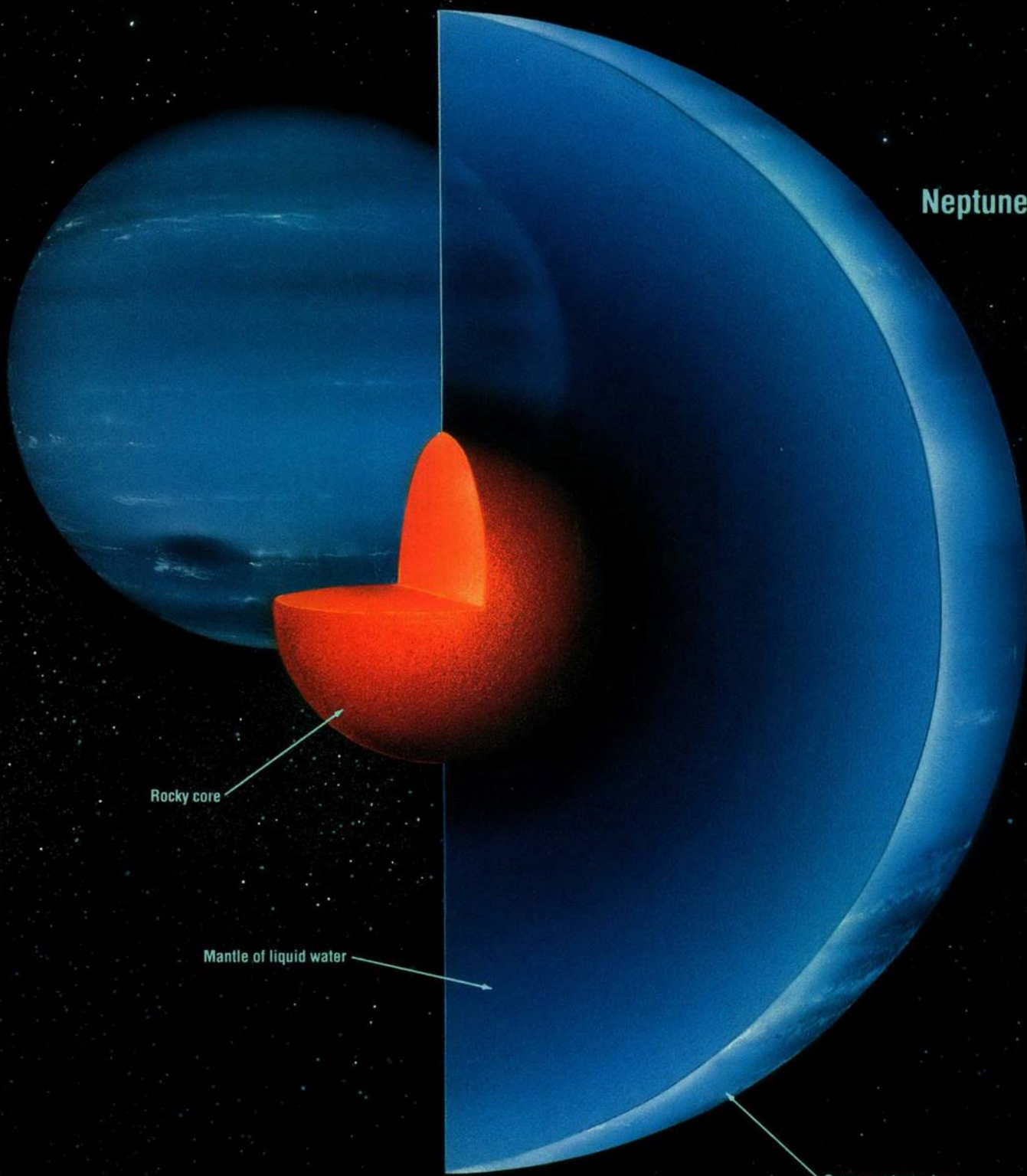
DESPITE EXTERNAL DIFFERENCES, Uranus and Neptune are probably similar in structure. Each has a rocky core covered with a mantle of liquid water, methane, and ammonia, and an immense "atmosphere" of hydrogen and helium gas. Painting by Paul DiMare.

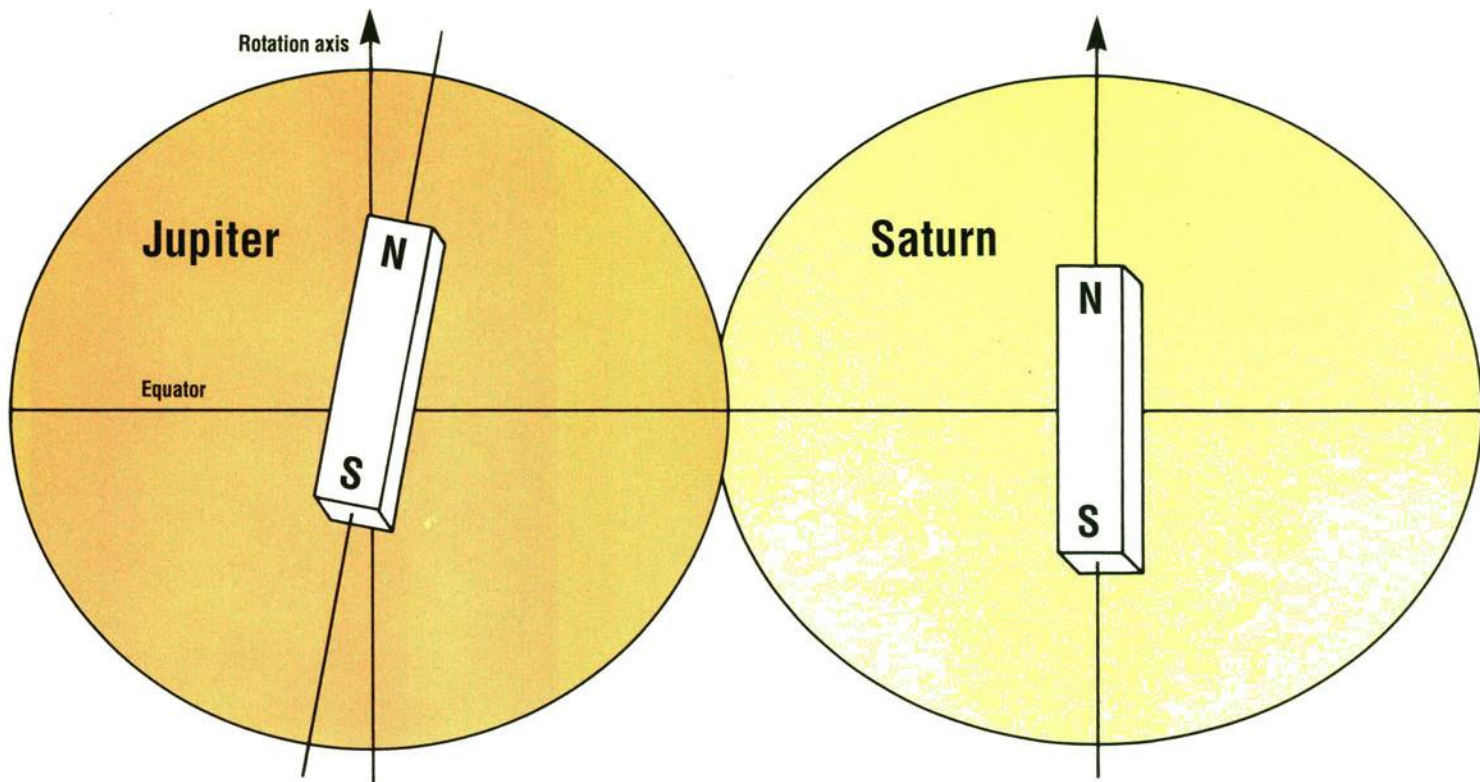
Neptune

Rocky core

Mantle of liquid water

Gaseous atmosphere





REACHING OUT INVISIBLY from the interior, the magnetic fields of Uranus and Neptune are tilted and displaced, showing that differences go deep between these two planets and Jupiter and Saturn. Diagram by Patti L. Keipe.

Probing Beneath the Clouds

Despite posing obvious difficulties for researchers, planetary interiors are not totally hidden. For example, Earth's structure has been mapped in detail by measurements of earthquake waves. Similarly, high-resolution images of the Sun show vibrations of the solar surface ("Sun-quakes"). These allow helioseismologists to infer the interior structure and deep fluid motions. Solar results can also help tell about the interior structures of Jupiter, Saturn, Uranus, and Neptune, because these four giant planets and the Sun are in large part variations on a single theme: a rotating sphere of hydrogen and helium gas.

Apart from surface motions, average density is the single most important "observable" in theoretical modeling of a planet's interior. Neptune is the densest giant planet overall at 1.640 grams per cubic centimeter. (Water's density is 1.000.) The next densest giant planet is Jupiter at 1.326, followed by Uranus at 1.267, and Saturn at 0.686. For two planets of the same size, a higher density signifies more heavy elements like oxygen, carbon, and nitrogen relative to light elements such as hydrogen and helium.

If density says something about the materials making up a planet, the oblateness of its gravity field shows the distribution of material inside the planet. A planet whose mass sharply divides into a dense core and a light envelope has a gravity field more nearly spherical than a planet whose mass spreads evenly throughout the interior. Although small, gravity-field differences are observable from Earth through measurements of ring precession (in the case of Uranus) and Triton's orbital regression (with Neptune).

Theoretical studies of giant planet interiors start with these facts, plus knowledge obtained from laboratory experiments on materials at very high pressures and temperatures. Planetary astronomers then proceed to build model planets and compare them to observations. The main uncertainty is a lack of precise information about how rocky and icy material behaves at the high pressures (20 million Earth atmospheres) and temperatures (7000 K) expected at the cores of Uranus and Neptune. Duly acknowledging the uncertainties, current theory for Uranus and Neptune has converged on a three-layer model for each (see pages 46-47).

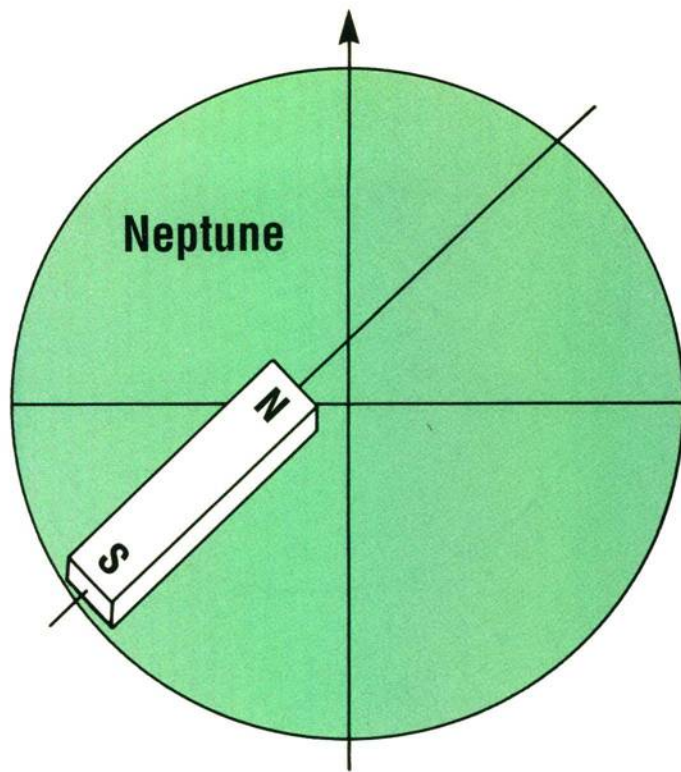
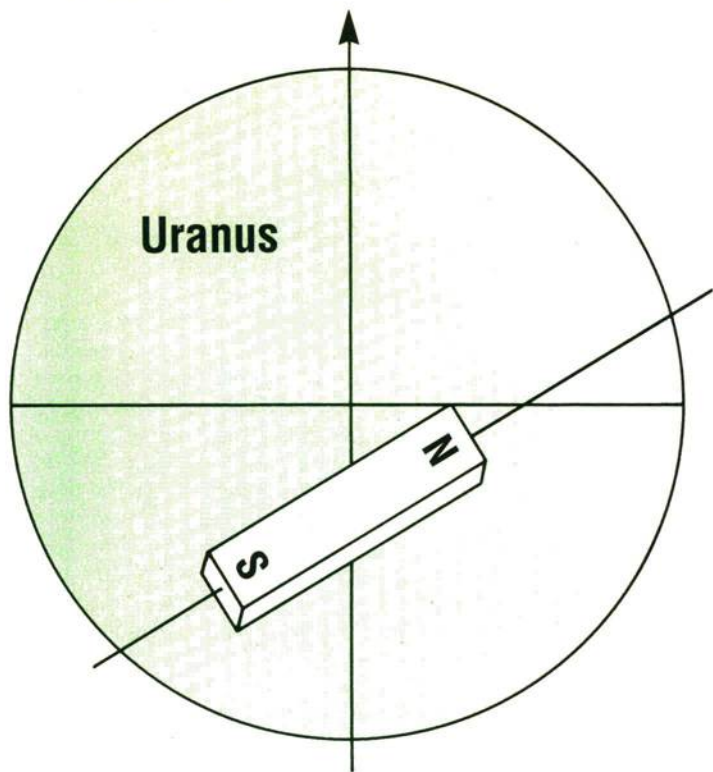
The outer layer is primarily hydrogen and helium gas, just as on Jupiter and Saturn. Going deeper, the gaseous layer gradually gives way to a denser intermediate layer composed of water, methane, and ammonia. As much as two-thirds of the mass of Uranus and Neptune may lie in this intermediate layer. At the bottom lies a core composed of rocky materials such as silicon and iron — it's as if each planet had an Earth tucked away at its center.

Invisible Webs: the Magnetic Fields

A planet's magnetic field forms a link between the deep interior (where it is generated) and the space surrounding the planet, into which it reaches, often out to dozens of planetary radii. Voyager found strong magnetic fields at each of the four giant planets. The phenomena associated with them are rich and challenging to understand.

An eternal wind of charged particles, the solar wind, streams from the Sun, blowing a planet's magnetic field back like a windsock. The boundary where the supersonic solar wind first senses a planet's magnetic field is called the bow shock. Closer to the planet is a second boundary, called the magnetopause, which marks the surface that separates the solar wind from the planet's magnetosphere.

Before the encounters, astronomers had no firm evidence that Uranus and Neptune even *had* magnetic



fields, although they anticipated them from the results at Jupiter and Saturn. Therefore, during the early Uranus encounter a few tense days ensued when *Voyager's* magnetometers remained silent well past the point where a magnetic field was expected.

Finally, just 10 hours before closest approach, the spacecraft crossed the telltale bow shock and the anxiety of the magnetic field investigators quickly turned to excited concentration as they began to map the Uranian magnetic field. The structure they found astonished them.

To describe a planet's magnetic field, the simplest way is to characterize it by its dipole moment, the magnetic field that a big imaginary bar magnet would have if buried deep inside the planet. This sounds over-simple, but it is actually realistic since most theories of planetary magnetism invoke a dynamo driven by the coupling of the planet's rotation to the circulation of deep, electrically conductive fluid. These theories also predict that a planet's magnetic dipole axis should tilt slightly away from the rotation axis — and this holds for Earth and Jupiter. (But not Saturn, where the field has no measurable tilt.)

The location of Uranus' dipole, however, was bizarre (see above). Tilting more than theory called for, the Uranian dipole was also displaced, or offset, from the planet's center. Right after *Voyager's* Uranus encounter, many scientists wrote off the tilt and offset as freaks of nature. They thought that either the large tilt related somehow to the fact that Uranus was tipped on its side, or that the Uranian magnetic field was undergoing a reversal in polarity, as has occurred on Earth in the past.

Then came Neptune. Its dipole showed a similar tilt — and an even greater offset! Thus, almost against their will, astronomers came to realize that the magnetic fields of Uranus and Neptune formed a new class unto themselves. Present thinking explains the large offsets by proposing that the magnetic fields of

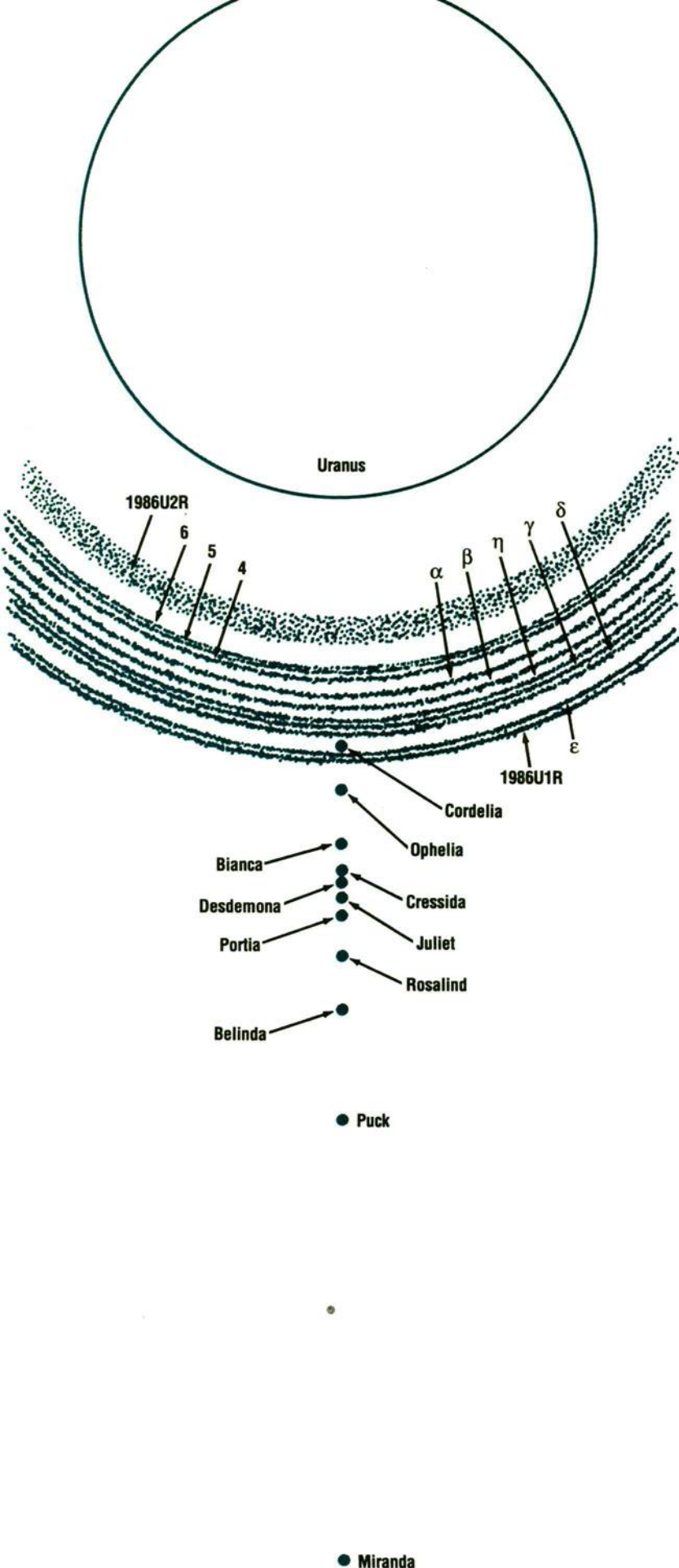
Uranus and Neptune are generated in their intermediate layers, not in their cores.

The unexpectedly large offsets of these two magnetic fields mean that the surface field strengths vary from place to place by a factor of ten: from a low of about 0.1 gauss to a high of about 1.0 gauss. (Earth's surface field strength is about 0.3 gauss.) Similarly, the large tilts of the two magnetic fields mean that the geometry of the field as it meets the solar wind changes continuously from pole-on to Earth-like as Uranus and Neptune rotate. This creates a complicated, dynamic magnetosphere.

Magnetic field effects can also say something about motions in the surface layers of both planets. For example, terrestrial lightning creates distinctive electrical outbursts, called whistler waves, that travel along magnetic field lines from one hemisphere to the other. At Jupiter, *Voyager 2* photographed huge lightning flashes on the dark side of the planet and recorded strong whistler waves. However, *Voyager* photographed no lightning at Uranus or Neptune, and although a search through the data for whistler waves yielded some possible candidates at Uranus, none were found at Neptune. This gives some indirect information about the meteorology of these planets. For example, lightning is usually associated with rain and strong wind shears, so a lack of it at Uranus and Neptune points to a lack of strong updrafts and precipitation for both.

Rings

From the deep interiors of Uranus and Neptune, let's step out into their surroundings and examine their ring and satellite systems. Saturn was once the only planet known to have rings, but it is now clear that all four giant planets have them. But Saturn's remain the most spectacular set in the solar system. Of all its rings, the narrow F ring may be most similar to the many narrow rings found encircling Uranus and Neptune. Since ring material tends to spread out relatively

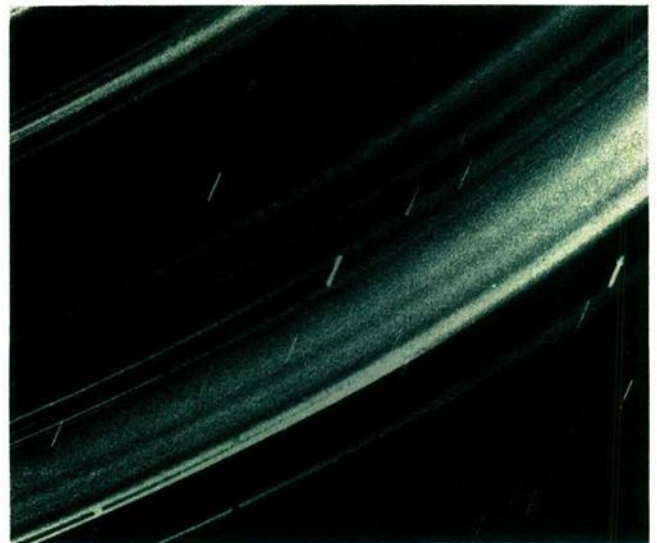


quickly, explaining a narrow ring is a challenging — and in most cases, still unsolved — dynamical problem, involving orbital resonances and gravitational confinement effects between ring material and attendant satellites.

The rings of Uranus and Neptune were detected first from Earth, when the planets passed in front of stars. Before and after being occulted by the body of the planet, starlight also winked off and on as the rings flanking the planet intercepted it. The first such discovery came in March 1977, when astronomers observed a stellar occultation by Uranus. They were hoping to get crucial new information about the Uranian atmosphere. What they got, in addition to the atmospheric data, was a totally unexpected ring system! By the time *Voyager* arrived at Uranus in 1986, a total of 9 narrow rings had been identified, several varying in width and having eccentric orbits. Astronomers tried the same occultation technique with Neptune and observed about 50 occultations before *Voyager* arrived, but with virtually no conclusive ring detections.

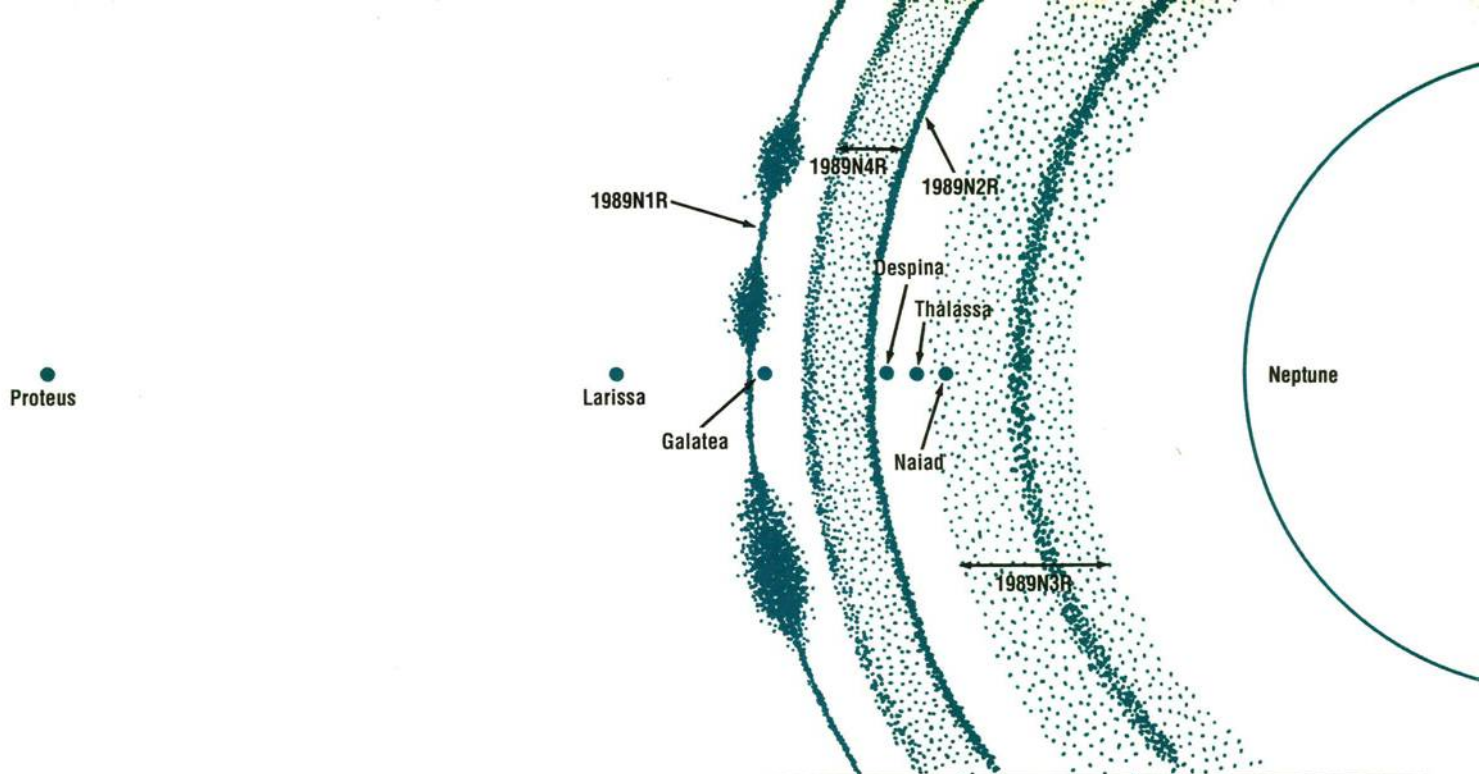
However, five Neptune occultations between 1981 and 1985 had shown good evidence of ring material. But there was a catch. The occulted star blinked out only on *one side* of Neptune, not both. This implied the rings were partial, or “ring arcs.” This was wholly new. Some rings, it is true, vary greatly in width and density around their circumference (most notably Uranus’ Epsilon ring). But these rings are still complete. The Earth-based discovery of ring arcs around Neptune was exciting and tinged with controversy; it also heightened suspense over what *Voyager* would find.

At Uranus and Neptune sunlight is hundreds of times weaker than on Earth. And unlike the relatively bright rings of Saturn, made primarily of “dirty snowballs,” the rings of Uranus and Neptune are composed of extremely dark material. They are so dark, and the sunlight out there is so feeble, that even if you rode



A 96-SECOND LOOK by *Voyager* at the dusty rings of Uranus turned stars into streaks, but revealed gauzy structure.

RINGS AND MOONS remain largely separate in the Uranian system. Only tiny Cordelia, barely 50 kilometers across, orbits within the ring system.



INTERWEAVING RINGS and satellites, Neptune's system of satellite objects appears to be more simply constructed than that of Uranus.

aboard *Voyager* you could not see the rings with your naked eye.

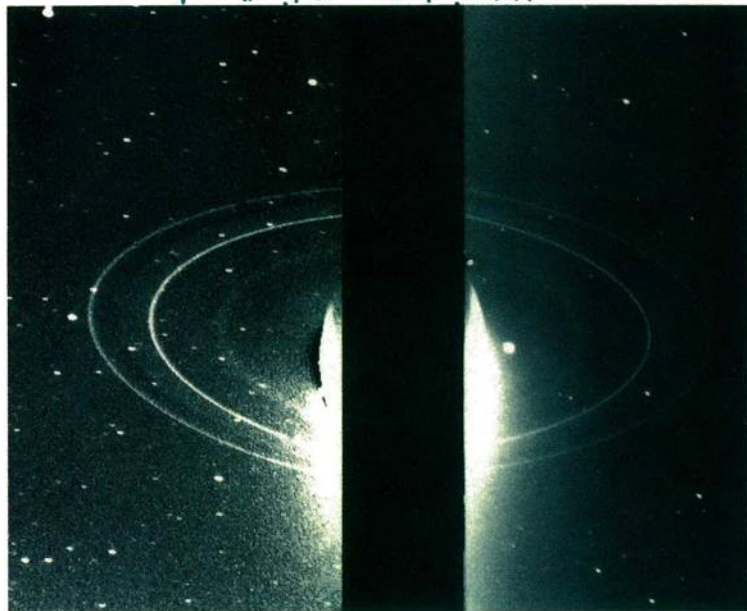
At present the ring arcs defy explanation. Collisions between the particles making up the arcs should spread the material into a uniform ring over about a decade unless a satellite in a resonant orbit prevents this. None were found in the right orbit so why the arcs continue to exist remains therefore a mystery.

Geologies of Ice

Uranus has the usual large number of satellites found around giant planets, but Neptune has only a few — it even had to borrow to get its only big satellite. The five largest satellites of Uranus, all known prior to *Voyager*, are (from innermost out) Miranda, Ariel, Umbriel, Titania, and Oberon. A systematic search with *Voyager's* cameras netted 10 more small satellites. One of them, Cordelia, orbits just inside the Epsilon ring; the others orbit outside the rings but inside the orbit of Miranda. Their orbits are nearly circular and lie in Uranus' equatorial plane. Just like the rings, the 10 new satellites are all quite dark, with reflectivities of only a few percent.

Material as black as charcoal is ubiquitous in the outer solar system. The rings and satellites of Uranus and Neptune are mostly dark and so also are comets. (Before it nears the Sun and forms bright tails of sublimated ices and dust, Halley's Comet is the darkest known object in the solar system.) This low reflectivity comes from a large amount of organic material on the surface that becomes very dark when exposed to ultraviolet light and cosmic rays.

Uranus and Neptune each have an attention-grabbing satellite. For Uranus this is Miranda and for Neptune it is Triton. Most of Miranda's surface is old cratered terrain. But Miranda also has large regions that look for all the world like scoops of marble-fudge ice cream. What caused them? No one is sure, al-



PAIRED IMAGES taken at different times show the same ring segments left and right, flanking a blocked-out Neptune. (Ironically, the ring arcs were on the other side of Neptune when each picture was taken!)

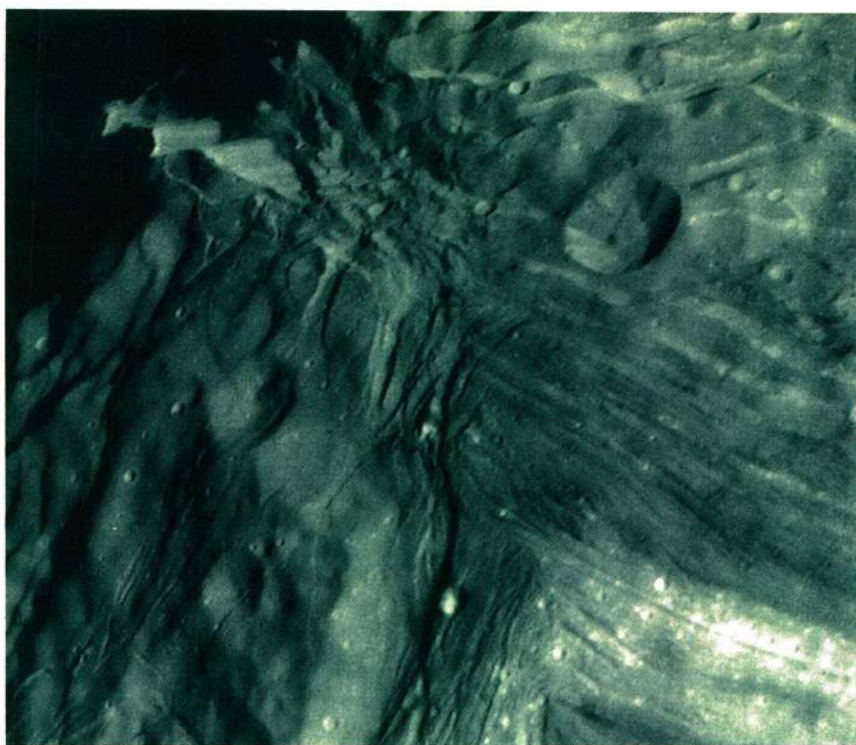
though two points stand out. First, planetary astronomers think Miranda has been shattered and reassembled at least once and perhaps many times in its history, thus eradicating the traces of its earliest history. Second, while the extremely cold ices that make up the bulk of Miranda and its siblings ought to be as hard as granite, scientists are not completely sure how to predict the behavior of such material in a big collision.

Prior to the *Voyager* encounter, Neptune was known to have two satellites, tiny Nereid and whopping Triton. Nereid is notable for a highly eccentric

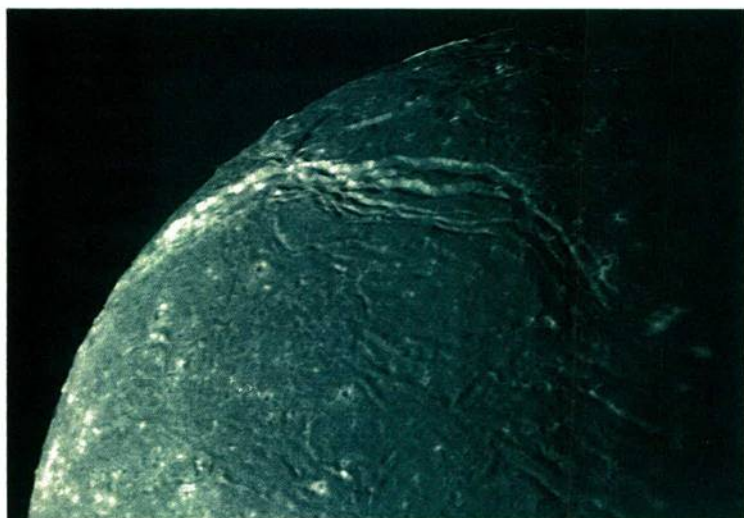
ICY GEOLOGY: THE MOONS OF URANUS



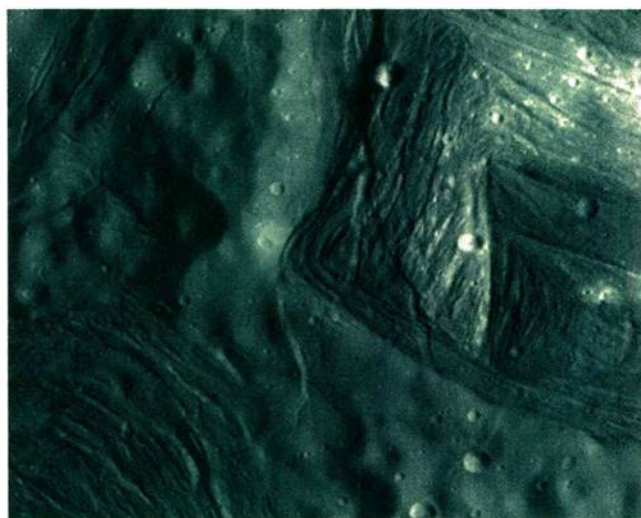
A JAGGED FAULT cuts the cratered face of Titania.



A 15-KILOMETER CLIFF (upper left) marks a spectacular fault on Miranda that merges into strangely patterned terrain (lower right).



THE LEADING HEMISPHERE of Ariel is more geologically complex than that of any large moon except Miranda.



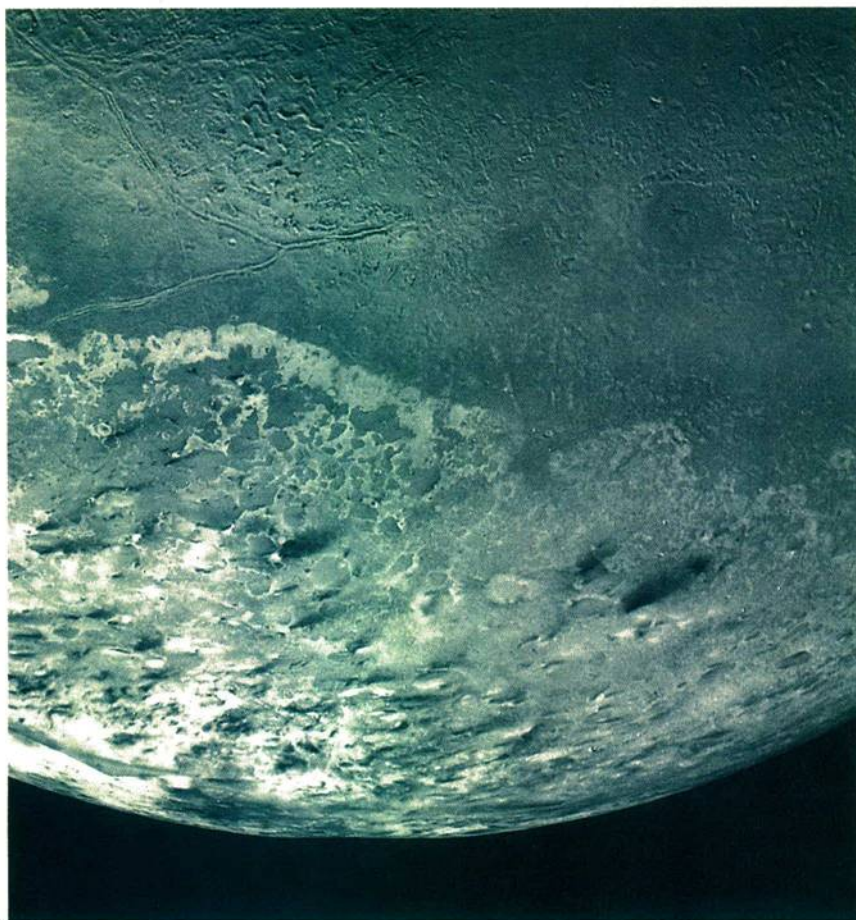
A FIRST-CLASS GEOLOGICAL PUZZLE, Miranda's "chevrons" may be areas of recent melting.

orbit, varying its distance from Neptune by a factor of seven during its 360-day-long orbit. *Voyager* discovered six new small satellites around Neptune, provisionally named 1989N1 through 1989N6. These are presumably mixtures of ices and silicates with an admixture of dark organic material. The biggest, 1989N1, is actually larger than Nereid but it was not discovered from the ground because it orbits too closely to Neptune and gets lost in the glare.

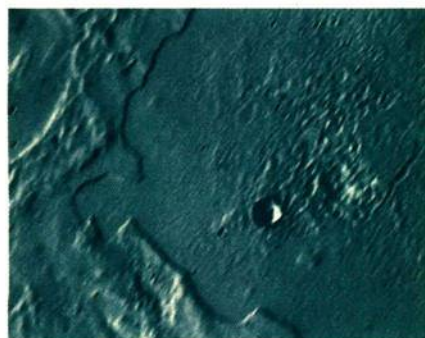
Massive Triton is a highly unusual body. It is the only major satellite in the solar system that orbits in a direction opposite to the spin of its host body. This strongly suggests that Triton was probably once a free object very much like Pluto. But Triton may best be appreciated from a geological standpoint. It contains a

marvelously diverse array of terrain, only some of which is explainable as yet. Triton has a thin atmosphere primarily of nitrogen and a surface temperature of 38 K (−391° F). The atmosphere shares certain similarities with that of Mars. As on Mars, the sublimation of the sunlit polar cap is important as a source for the atmospheric gas itself and as a source of pressure differences to propel winds across its barren craterscape. And like Jupiter's moon Io, Triton has volcanic activity in the form of geysers. Clouds can be seen in Triton's atmosphere and wind streaks and geyser plumes are being studied to get a sense of the wind shear and wind direction.

Triton is also serving as a surrogate for Pluto, the last of the planets for which only Earth-based observa-



DARK WIND STREAKS on Triton's south polar cap are probably only a few thousand years old and show that prevailing winds blow northeast.



THE GEOLOGICAL SMORGASBORD on Triton ranges from large flooded impact craters (left) to rolling, lightly cratered terrain (center) to the mysterious "cantaloupe" terrain (right). Scientists think Triton's surface is geologically young.

tions are available. A Pluto reconnaissance mission may yet be launched (see "Viewpoints," July 1990). But in the meantime planetary scientists are poring over photos of Triton in the hopes of forging links between *Voyager's* close-up looks and ground-based views of both objects.

With the *Voyager* mission alone, NASA's deep-space exploration program gave us many distant worlds and moons to study up close. We now know that Uranus and Neptune are truly twin giants of the outer solar system. We know that they have very similar sizes, colors, temperatures, rotation periods, cloud-top winds, and magnetic fields. On the other hand, they have very different obliquities, internal heat sources, and storm systems. Both are encircled by nar-

row rings and small satellites made of extremely dark material, although intriguing differences (such as Neptune's ring arcs) continue to tantalize and puzzle.

As scientists begin to solve many of the outstanding problems in planetary and Earth science, they continually uncover challenging and exciting new problems. Many of these were not even realized before the advent of deep-space exploration and yet solving them will be critical to our understanding of *all* planetary systems, including Earth's. □

Timothy Dowling is an assistant professor in the department of Earth, atmospheric, and planetary sciences at MIT.

ICY GEOLOGY: NEPTUNE'S TRITON



A HAZE LAYER in Triton's nitrogen atmosphere appears to be about 3 kilometers thick.



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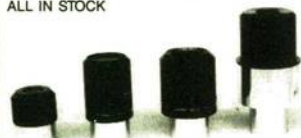


IC 405, "The Flaming Star Nebula," in Auriga. 45 minute exposure by Martin Germano using an 8" f/5 telescope with LUMICON 2" Newtonian EASY-GUIDER, and 2415 film hypersensitized in a LUMICON Model 300 Hyper-Kit. IC 405 is faint and is seen best visually with either a LUMICON UHC Filter, or preferably a LUMICON H-Beta Filter.

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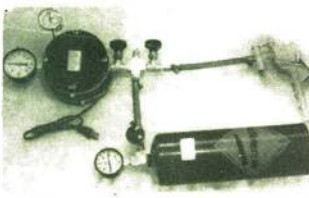
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Coma 1 inch off-axis 17 1/2" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2 1/4" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

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1.8x Multiplier Lens

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FROM
\$49.50



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LUMICON now offers 3 different low-profile helical focusers. They stand only 1 1/4"-1 1/2" above the telescope tube. Use the 1 1/4" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.
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2" adapter for C-8, Meade 2080, etc. \$26.00
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2" adapter for Takahashi E-130, 160 \$59.50

North

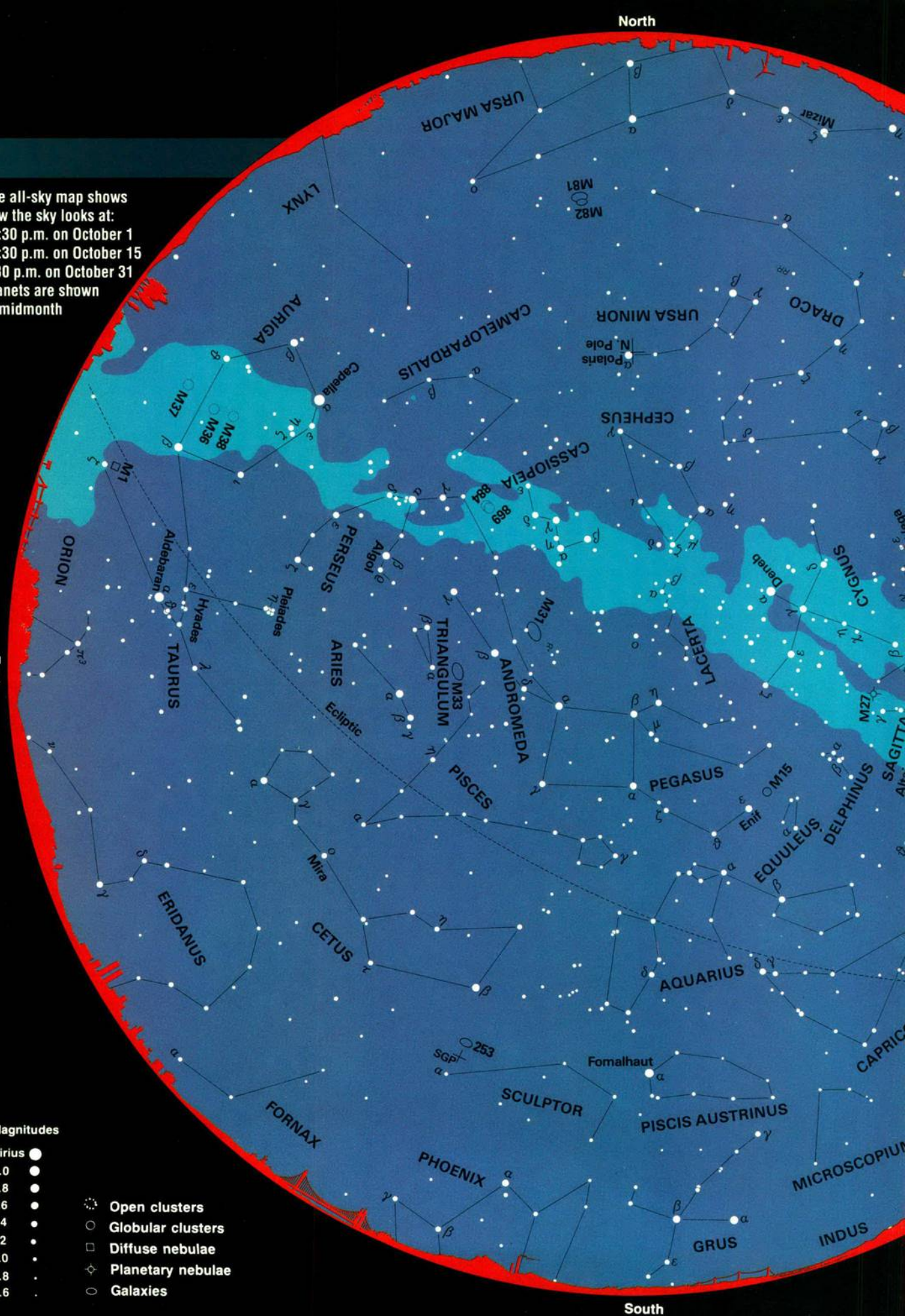
The all-sky map shows
how the sky looks at:
11:30 p.m. on October 1
10:30 p.m. on October 15
8:30 p.m. on October 31
Planets are shown
at midmonth

East

Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 ●
3.2 ●
4.0 ●
4.8 ●
5.6 ●

○ Open clusters
○ Globular clusters
□ Diffuse nebulae
◇ Planetary nebulae
○ Galaxies



Sky Almanac

October 1990

A HARVEST MOON IN OCTOBER

The Harvest Moon is the Full Moon closest to the September equinox, and this year it occurs on October 4. On evenings after the 4th, the nearly Full Moon rises about thirty minutes later each night.

ORIONIDS PEAK ON OCTOBER 21

Streaks of light will pepper the predawn sky on October 21 and 22, when the Orionid meteor shower is at its best. You can expect to see roughly twenty-five of the shower's swift meteors per hour on those two mornings.

MIRA AT ITS BRIGHTEST

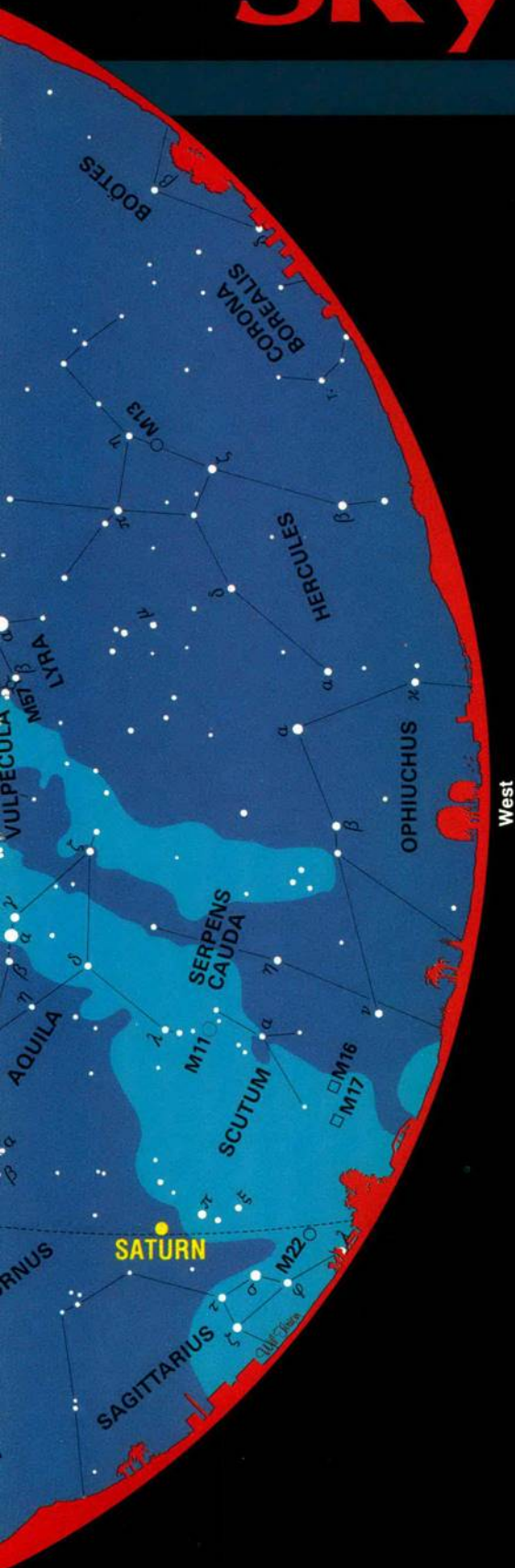
The extraordinary variable star Mira is near its maximum brightness this month. The reddish star is easy to spot with the naked eye in the southeastern sky before midnight.

COMET ENCKE AT PERIHELION

Comet Encke reaches perihelion on October 28 and is well placed in the morning sky during the first two-thirds of the month. The comet is brightest around midmonth, when it glows at 7th or 8th magnitude, and is an easy target for observers with large binoculars or a telescope.

Calendar of Events

- | | |
|--|--|
| 4 Full Moon is at 8:02 a.m. EDT | 22 Mercury is in superior conjunction
The Moon passes 0.6° north of Antares, 4 a.m. EDT |
| 6 The Moon is at perigee (225,710 miles from Earth), 2:30 p.m. EDT | The Moon is at apogee (252,167 miles from Earth), 11:59 a.m. EDT |
| 8 The Moon passes 5° north of Mars, 3 p.m. EDT
Draconid meteor shower peaks | 24 Comet Levy is at perihelion |
| 10 Last Quarter Moon is at 11:31 p.m. EDT | 25 The Moon passes 1.1° south of Saturn, 1 p.m. EDT |
| 12 The Moon passes 1.0° south of Jupiter, 4 p.m. EDT | 26 First Quarter Moon is at 4:26 p.m. EDT |
| 18 New Moon is at 11:37 a.m. EDT | 28 Comet Encke is at perihelion |
| 20 Mars is stationary | |
| 21 Orionid meteor shower peaks | |



DELAY IN MOONRISE (expressed in minutes)

Latitude	October 4	June 8	December 31	March 11
20°	44	50	69	50
25°	41	50	71	52
30°	38	50	73	55
35°	35	49	75	59
40°	31	49	78	61
45°	27	48	82	66
50°	21	46	85	70
55°	14	44	93	76
60°	5	38	106	84

The Harvest Moon rises only about half an hour later on successive evenings, but the exact delay varies with latitude. The delay in the time of moonrise from the night of the Full Moon to the next night is shown for several latitudes at various Full Moons.

THE HARVEST MOON SHINES ON on October 4 this year, and over the next several evenings the light of the nearly Full Moon will bathe the landscape.

A LATE-SEASON HARVEST MOON

The legendary Harvest Moon can be seen ascending in the east on the evenings around October 4. To many people this Full Moon looks brighter and yellower than other Full Moons, but it isn't really. It's noticeable for another reason.

The Moon rises only about thirty minutes later on successive evenings around the date of Full Moon at this time of year, compared with an average delay of about fifty minutes. Thus, an almost-Full Moon appears to rise at nearly the same time each evening. In the days before artificial lighting, the light from this Moon benefited farmers bringing in their crops — hence the name Harvest Moon.

The key to this phenomenon is the shallow angle of the ecliptic relative to the eastern horizon in the evening at this time of year. The ecliptic is the plane of Earth's orbit around the Sun or, inversely, the apparent path around the sky traced by the Sun throughout the year. The Moon and planets, whose orbits lie near to the same plane as Earth's orbit, also travel more or less along this path across our sky.

As the Moon orbits around Earth, it moves eastward along the ecliptic. This eastward motion causes the Moon to rise later each day, by about fifty minutes on average. In the early evening hours at this time of year, however, the ecliptic lies nearly flat relative to the eastern horizon. The Moon still moves along the ecliptic, but its eastward motion translates into a more sideways motion along the horizon toward the north. So the delay in moonrise from one day to the next is shorter.

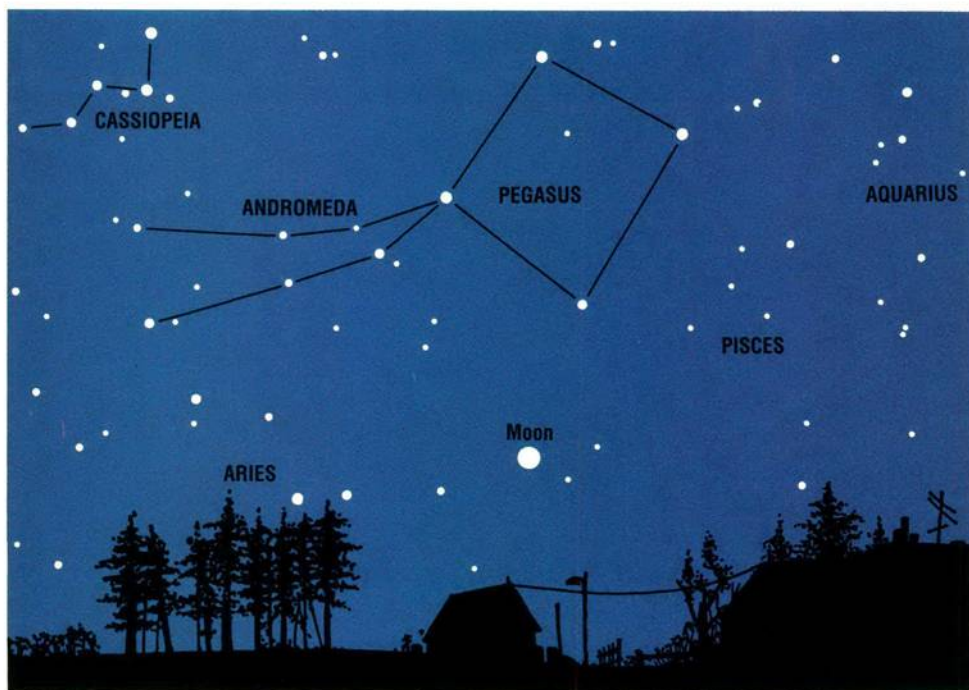
A GOOD YEAR FOR THE ORIONIDS

Sometimes the Moon is desired and admired. At other times, however, it's in the way! One of those times is when it is in the sky during the peak hours of a shower of meteors, or "shooting stars." Bright moonlight illuminates the sky so effectively that all but the brightest meteors get lost in the glare.

Luckily, this year's Orionid meteor shower is at its best on the mornings of October 21 and 22, when the Moon is a slender crescent that sets shortly after the Sun sets. The Orionid shower is the third most reliable meteor shower of the year, after the famous Perseid shower of August and the Geminids of December.

Observers can expect to see a couple of dozen meteors per hour before dawn on the 21st and 22nd, which works out to one every few minutes. If this is a lean year, however, you might see only a handful of meteors all night. If it's a good year, the meteors may rain down at a rate of one a minute. Orionid meteors travel fast — over 40 miles per second — and many leave trains lasting a second or two.

Most meteor showers are best in the hours after midnight, and this one is no exception. To get the best view possible, you need to find an open area far from city lights. Take a lawn chair or blanket along to lie on and dress warmly — nights in late October can get pretty cold.



No particular region of the sky is likely to have more meteors than any other. Just recline comfortably and gaze up at the sky.

JUPITER AND THE BEEHIVE

Jupiter begins October almost directly along our line of sight to a prominent star cluster, called the Beehive or Praesepe (M44). The cluster is the most exciting feature of the dim constellation Cancer the Crab.

The planet and star cluster ascend over the east-northeastern horizon a bit after midnight and by the beginning of morning twilight are well up in the east. Brighter than any star, Jupiter is extremely conspicuous at magnitude -2.0 . The integrated light of the cluster equals that of a 3rd-magnitude star. The cluster is harder to see than a star would be, however, because its light is spread over a diameter of about three Full Moons. You'll need a dark sky to get a good naked-eye view of the Beehive, although even then the cluster appears as a dim, hazy patch. For the best view of this rare celestial alignment, use binoculars.

OCTOBER'S PLANETS

Saturn lies low in the south-southwest as night falls this month. It shines at magnitude 0.5 from a location in eastern Sagittarius. Saturn has lingered in Sagittarius for some years now, but it will cross into Capricornus early next year. You can watch Saturn creep toward Capricornus now that the planet has resumed its eastward motion.

Although Saturn is moving eastward relative to the stars, Earth's motion around the Sun is carrying the planet westward relative to our horizons. Saturn sets only a few hours after twilight ends in late October and will disappear behind the Sun around the end of the year.

The next planet to appear is Mars, which rises in mid-evening. With its great brightness and warm, ruddy color, Mars is impossible to mistake for any other object. It shines at magnitude -0.9 in early October and brightens to magnitude -1.6 by the end of the month. Then it is brighter than any star and nearly as bright as the planet Jupiter.

Earth will slide between Mars and the Sun late next month, when the Red Planet will be at opposition. Between now and then, Mars will brighten still more and continue rising earlier each evening.

Jupiter can be found in the east before dawn when October begins. By the end of the month, it is high in the southeast before sunrise. Jupiter is easy to spot because it is brighter than any star, shining at magnitude -2.0 . Contrast its brightness to that of Mars, which lies in the southwest at dawn.

You can glimpse the elusive innermost planet, Mercury, in early October. It lies 8° above the eastern horizon thirty minutes before sunrise on the 1st, when it shines at magnitude -1.0 . With each passing day, it sinks lower in the sky, but it also brightens slightly, so you should be able to follow it through the first week of October.

Venus joins Mercury on the far side of the Sun this month. The bright planet won't return to visibility until mid-December, when it will appear in the evening sky.



AN ORIONID METEOR streaks past the Pleiades in this 1976 photo by Seth Horowitz. This year the Orionid shower is at its best on the mornings of October 21 and 22.

THE CRESCENT MOON SLIDES PAST Saturn on the evening of October 25. Look for the pair in the south-southwest above Sagittarius after twilight ends.



OCTOBER'S STARRY SKY

Mira the Wonderful is one of the sky's most famous variable stars. At maximum brightness it can be seen easily with the naked eye as a reddish star in Cetus the Whale. At minimum light, however, it cannot be seen without optical aid. Astronomers expect Mira to peak in brightness in late September or early October, so look for it wheeling slowly across the southern sky with its companion, the whale.

Mira's comings and goings have been followed by astronomers for well over three hundred years. The star takes about eleven months to complete a cycle from maximum to minimum brightness and back again. (For more about what makes Mira tick, see this month's "Through the Eyepiece.")

Perhaps because Mira is so fascinating, we often overlook its host constellation, Cetus. Yet Cetus plays a central role in one of the best known and best loved of all Greek myths. Cetus is located in a "watery" region of the autumn sky, along with Pisces the Fish, Piscis Austrinus the Southern Fish, Capricornus the Sea-Goat, Eridanus the River, and so on. We call Cetus a whale, but the Greeks simply knew him as a generic sea monster.

According to the legend, Cassiopeia, the queen of Ethiopia, was very vain. She often boasted that her beauty rivaled that of the sea nymphs. The nymphs, needless to say, were miffed. They complained to Neptune, god of the sea, who sent Cetus — a horrible monster — to ravage Ethiopia's shores. Cassiopeia's husband, Cepheus, then complained to Zeus, the king of the gods. Clearly, some compromise had to be reached!

But Cepheus was dismayed at Zeus' reply. Zeus informed him that he must chain his lovely daughter Andromeda to a rock by the sea. She would have to become a sacrifice to the dreaded Cetus.

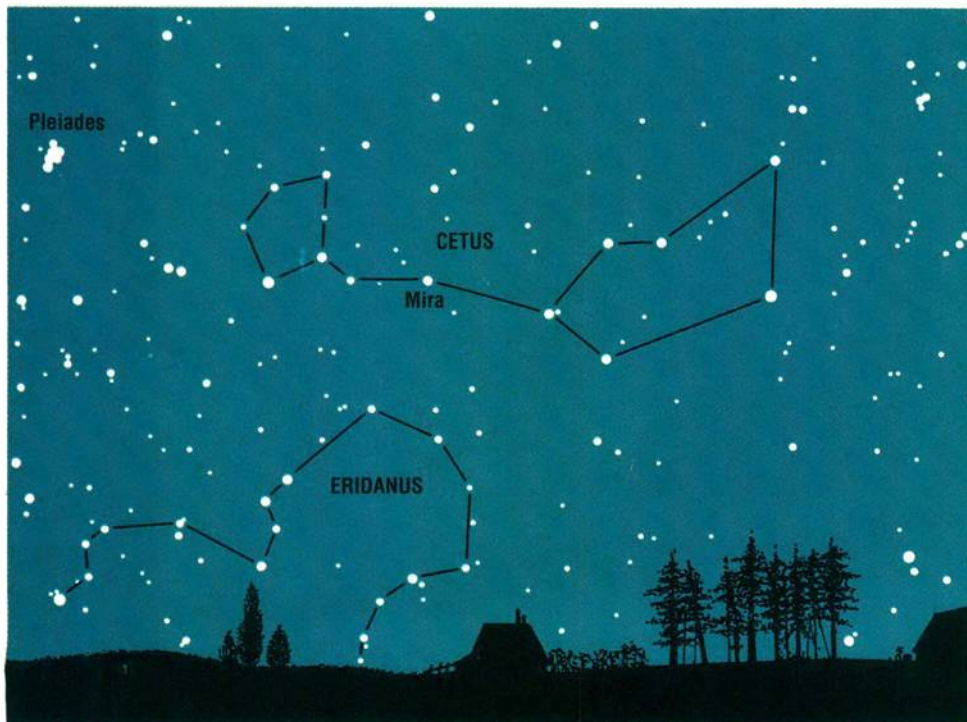
Meanwhile, in another part of the world, the mighty hero Perseus had just slain and decapitated Medusa, the only mortal among the three Gorgon sisters. With snakes on her head in place of hair, she

was said to be so ugly that the sight of her turned any onlooker to stone. Perseus had placed her head in a bag and was flying on Pegasus the Flying Horse when he spied Andromeda chained to the rock. Thinking quickly, he offered to save her and kill the monster in return for Andromeda's hand in marriage. Cepheus agreed, at which point Perseus pulled Medusa's head from the bag, transforming Cetus to stone.

The princess and the country were saved. This so pleased the gods that they transported the players — king, queen, princess, hero, horse, and sea monster — to the heavens, where we see them today. □

Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

MIRA THE WONDERFUL is a ruddy point of light in the southeast during the late evening hours this month. This famous variable star is near peak brightness now and rivals the brightest stars in its constellation, Cetus.



THE RETURN OF COMET ENCKE

An old standby reappears this autumn for our viewing pleasure. It's periodic Comet Encke, an object that has provided generations of astronomers with a dependable comet to observe. With the shortest period of any known comet — 3.3 years — Encke returns to Earth's vicinity often enough that most backyard observers get several opportunities to observe it.

Comet Encke is a morning object during September and October. It first comes within easy range of 6-inch telescopes in mid-September, when it glows at 10th magnitude just north of Castor and Pollux, the two brightest stars in Gemini. By the beginning of October, Encke brightens to 8th magnitude and pushes into the head of Leo, where it lies just below Mu Leonis. In binoculars or a telescope, expect the comet to show a large coma 10' in diameter or larger that appears slightly brighter toward the center. You may also see a faint, narrow gas tail about 1° long pointing directly away from the Sun.

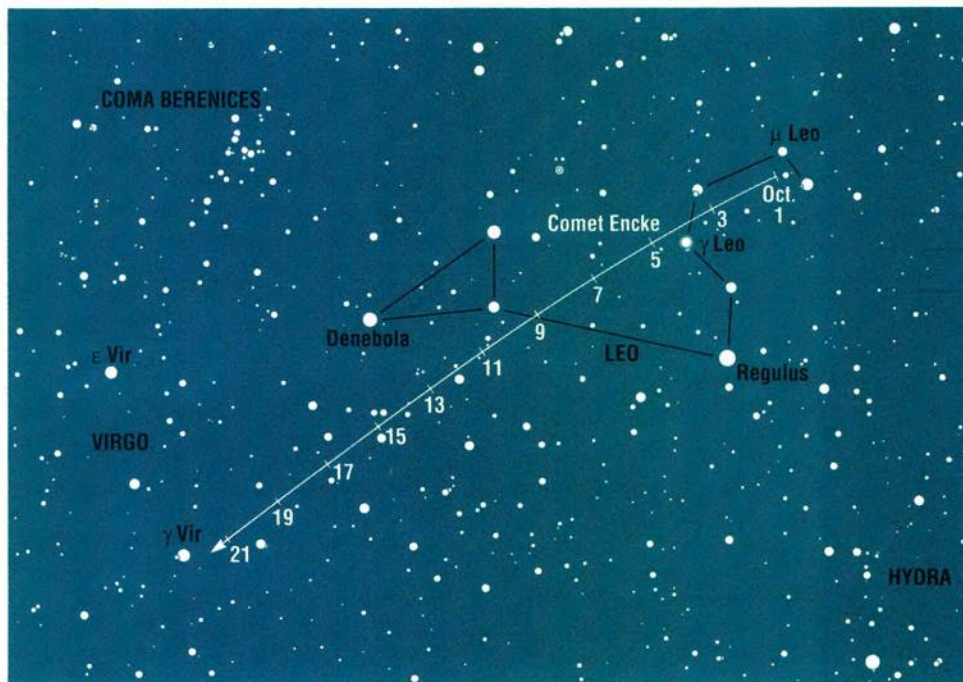
The nearly Full Moon starts to interfere with your view of Encke after the first couple of days of October. By mid-October the comet is at its brightest, around magnitude 7.5, and moving through western Virgo. You can probably follow Encke until about October 20; after that the comet lies too close to the eastern horizon as twilight begins to get a good view. Comet Encke reaches perihelion, its closest point to the Sun, on October 28 and is then lost in the twilight glare. (For more details on observing Comet Encke throughout this apparition, see "Comets Encke and Levy: Something Old and Something New," in the September issue.)

The best times to observe Comet Encke in October are very early in the month, before the approaching Harvest Moon interferes, and around the middle of the month, when the waning crescent Moon provides only minor interference. The comet's headlong plunge toward the horizon diminishes its visibility in the second half of October. Is there anything you can do about this? If you follow a few simple tips, you can still observe Encke during this period.

First, pick an observing location where you can block the Moon's light behind a building, tree, or hill. Second, if the weather is cooperative try to observe on a night when the humidity is low. This minimizes the scattering of moonlight. Third, use a bit more magnification than you would on a moonless night. This spreads out the background moonlight and makes it less of a nuisance. And finally, arrive at your observing site about three hours before sunrise to give your eyes plenty of time to adapt to the dark.

MIRA IS "WONDERFULLY" BRIGHT

The famous pulsating variable star Mira, or Omicron (o) Ceti, shines at naked-eye visibility this month. Mira varies with a period that averages 332 days, which means it reaches maximum brilliance about



COMET ENCKE'S BEST APPARITION in the last ten years winds down this month. Look for the 7th- or 8th-magnitude comet during the first three weeks of October as it moves through Leo and Virgo. Positions are shown for 6 a.m. EDT (5 a.m. CDT, 4 a.m. MDT, and 3 a.m. PDT).

COORDINATES FOR COMET ENCKE

Date	R.A. (2000) Dec.
Oct. 1	9h54.6m 24°21'
Oct. 3	10h12.3m 22°10'
Oct. 5	10h29.4m 19°51'
Oct. 7	10h45.9m 17°27'
Oct. 9	11h01.8m 14°59'
Oct. 11	11h17.2m 12°29'
Oct. 13	11h32.1m 9°57'
Oct. 15	11h46.6m 7°25'
Oct. 17	12h00.9m 4°52'
Oct. 19	12h15.0m 2°20'
Oct. 21	12h29.2m -0°11'

MARTIAN CENTRAL MERIDIANS

Date	Central Meridian
October 1	14°
October 4	346°
October 7	319°
October 10	291°
October 13	263°
October 16	236°
October 19	208°
October 22	181°
October 25	154°
October 28	126°
October 31	100°

Observe Martian features by using this table, which gives the central meridian of Mars at midnight EDT (11 p.m. CDT, 10 p.m. MDT, and 9 p.m. PDT), with the map on page 77 of the September issue. To find the central meridian for other dates and times, subtract 9.1° for each day after a listed date and add 14.6° for each hour after the quoted time.

THE SHADOW OF SATURN'S DISK

hides a small portion of the ring system from our view this month, much as it did in this photo taken in 1969 by the Lunar and Planetary Lab.



a month earlier each year. This year it is expected to be at its brightest in late September or early October.

Use the finder chart on page 60 to locate Mira. It's easy to pick out — Mira is a reasonably bright naked-eye star when it's at maximum brightness. However, no one can say for sure exactly how bright Mira will appear. Over the nearly four hundred years Mira has been observed, its peak brightness has varied considerably. On average, Mira shines at about magnitude 3.5 when brightest, but it occasionally reaches 2nd magnitude and once, in 1779, it approached 1st magnitude. At other times it struggles to reach 4th magnitude. At minimum brightness Mira is much more consistent, usually bottoming out at about magnitude 9.5.

What causes this six-magnitude roller coaster? Mira is a pulsating variable star, which means it varies in size as well as in brightness. But the key factor in its variability is its changing temperature. At maximum light Mira is a relatively warm 2500 kelvins, while at minimum light it is one of the coolest stars known at about 1900 kelvins. When it is cool it emits less total energy and a larger percentage of the energy it does emit is invisible infrared radiation.

This makes Mira interesting observationally in two ways: the star not only varies in brightness but also changes color. As Mira dims, it radiates mostly red and infrared light. Because we can't see the infrared, Mira appears to be getting redder. Conversely, as Mira brightens, it radiates more visible light and its color shifts toward orange.

MARS APPROACHES OPPOSITION

As Mars prepares for its opposition in late November, so should you. The Red Planet measures over 15" in apparent diameter at mid-month and is 17" across at the end of October. With Mars appearing this large, lots of surface detail should be visible on the Martian disk. It's especially worthwhile to view the planet in the wee hours of the morning, when it is highest in the sky.

There are several reasons you should start observing Mars this month, if you haven't already started. First, the surface markings on Mars are subtle. To see them through a telescope requires a trained eye, something you can't pick up in just one or two nights of observing. Second, although the Red Planet will be visible in the evening sky come December, it appears just as big in your eyepiece this month as it will then and the weather is much more conducive to observing now. Third, Mars will appear only slightly larger at opposition in November (18" in apparent diameter) than it does in October, so the amount of surface detail visible will be about the same.

When you observe Mars, remember that the planet presents nearly the same face to us from one night to the next. That's because Mars takes only 37 minutes longer to rotate than Earth does, so the longitude of the Martian meridian facing us at a given

time on one night changes by only about 10° by the same time the following night.

This means you would need to observe Mars for nearly forty nights running before the same face returns to view at the same hour of the evening. Thus, the hemisphere you observe in mid-October is the same hemisphere you'll observe at opposition. To see what's visible when you plan to observe Mars, use the table of central meridian crossings on page 62 along with the map of Mars on page 77 of the September issue.

TELESCOPIC PLANETS

As October begins, Mercury is on the down side of its best morning apparition of 1990. It was at greatest elongation on September 23/24, when it was 18° west of the Sun, but it is now heading rapidly toward superior conjunction, which occurs on October 21/22. On October 1 Mercury lies 8° above the eastern horizon thirty minutes before sunrise. It is a -1.0 -magnitude object showing a $5.9''$ -diameter, 77-percent illuminated disk. By October 10, the last day you can reasonably expect to see it, the innermost planet glows at magnitude -1.2 and its $5.1''$ -diameter disk is 95-percent illuminated.

Jupiter is now high in the sky as morning twilight approaches and is well placed for telescopic observations. The giant planet measures $36''$ in diameter this month and is brilliant at magnitude -2.0 .

As this issue goes to press, there is still no sign that the giant planet's South Equatorial Belt is returning to prominence. Still, Jupiter's dynamic atmosphere bears watching as the planet nears its January opposition. As with Mars, you'll be able to see more detail in the Jovian cloudtops at opposition if you train your eye to see it beforehand.

Saturn is a 0.5 -magnitude object in the evening sky during October and has a disk measuring $17''$ in apparent diameter with rings spanning $38''$. Saturn reaches quadrature this month, which means that the planet's phase is as large as it can get. For most planets, quadrature is a time when you can see a disk that is less than 100-percent lit, but Saturn is so far from Earth that this effect is minuscule.

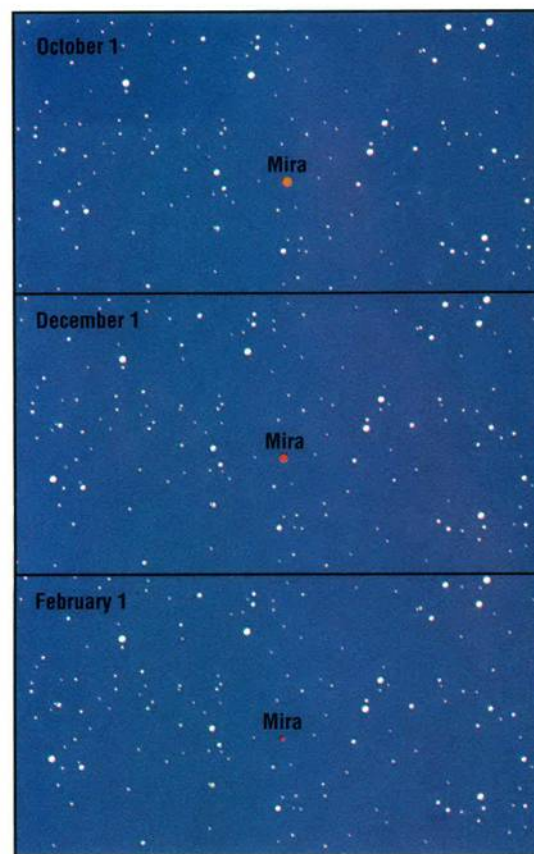
There is one observational effect to Saturn's quadrature that is worth looking for, however. At quadrature a planet's shadow falls at the largest distance from the planet as it can. In Saturn's case, we see the shadow cast onto the rings. Instead of completely encircling the planet as they usually do, the rings of Saturn appear to stop just before they pass behind the planet's disk.

Both Uranus and Neptune continue to follow Saturn through Sagittarius this month. Uranus glows at magnitude 5.7 and its blue-green disk measures $3.6''$ in apparent diameter. Neptune's blue-gray disk appears $2.2''$ across and glows at magnitude 7.9. □

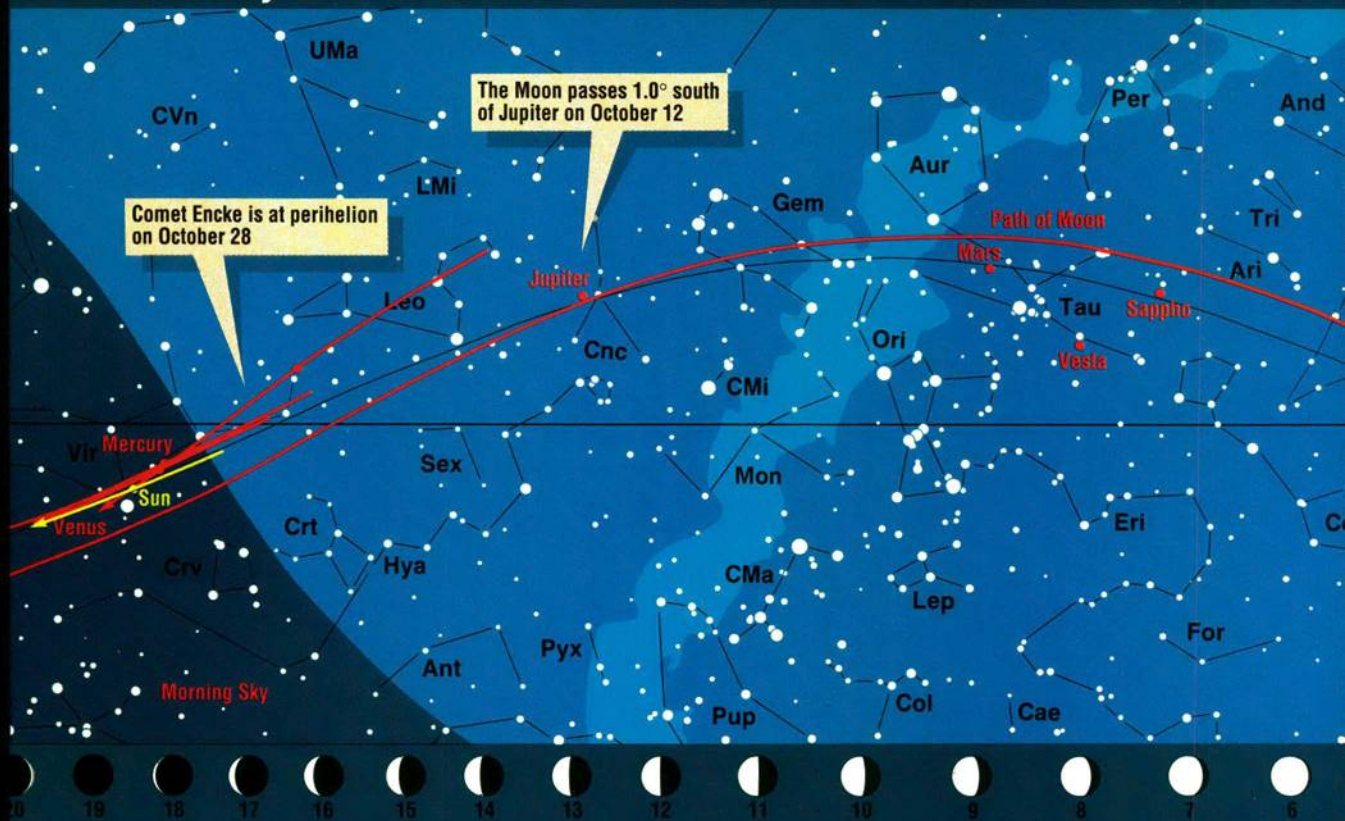
Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He is leader of the data management team on the Ulysses project, which is scheduled for launch this month.



MIRA APPEARS BRIGHT in October, just as it did in Ronald Royer's photo from November 1989 (above). Be sure to observe Mira as it fades dramatically and grows redder over the next several months (below).



The Solar System October 1990



10"



Planet	MERCURY	MERCURY	VENUS	MARS	MARS
Date	October 1	October 31	October 15	October 1	October 31
Magnitude	-1.0	-0.9	-3.9	-0.9	-1.6
Angular Size	5.9"	4.7"	9.8"	13.7"	17.0"
Illumination	77%	99%	100%	89%	96%
Distance (AU) from Earth	1.136	1.436	1.710	0.685	0.552
Distance (AU) from Sun	0.319	0.458	0.721	1.438	1.473
Right Ascension (2000.0)	11h34.3m	14h42.0m	13h04.6m	4h42.7m	4h50.2m
Declination (2000.0)	4°44'	-16°00'	-5°28'	21°08'	22°32'

Jupiter's Moons

Dots display positions of Galilean satellites at 9 UT on date shown. South is at top to match the view in a telescope.

1 Europa

2

3 Io

4 Ganymede

5 Callisto

6

7 Jupiter

8

9

10

11 Ganymede

12 Europa

13

14 Callisto

15

16

17 Io

18 Jupiter

19

20

21

22 Jupiter

23

24

25 Ganymede

26

27 Io

28

29 Callisto

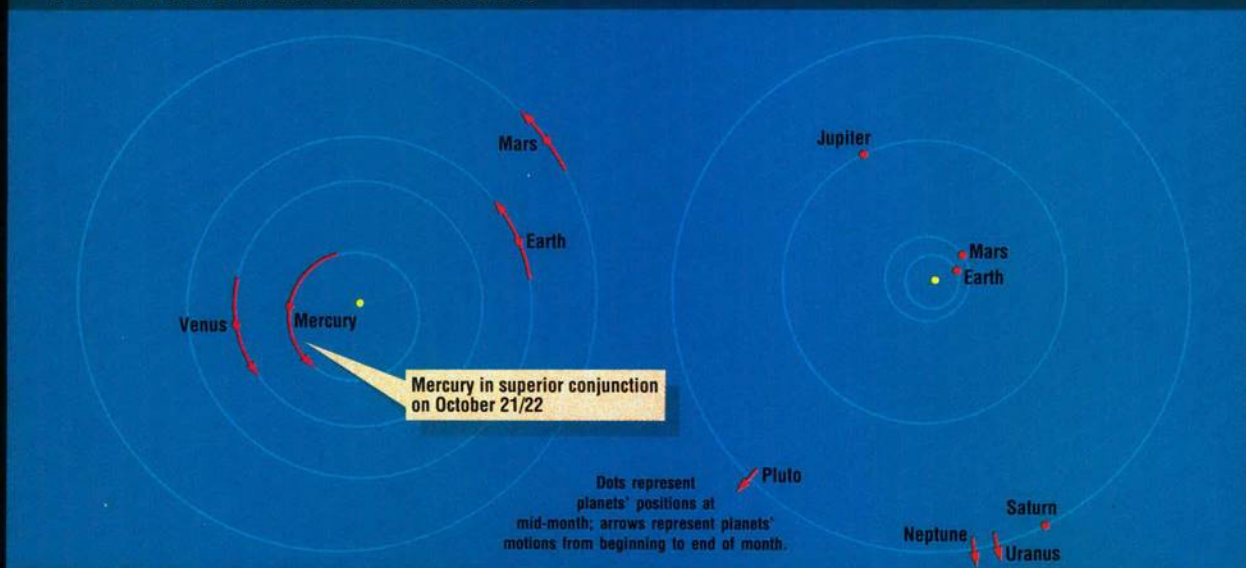
30 Europa

31



JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
October 15	October 15	October 15	October 15	October 15
-2.0	+0.5	+5.7	+7.9	+13.8
35.8"	16.6"	3.6"	2.2"	0.1"
99%	100%	100%	100%	100%
5.493	9.990	19.672	30.352	30.531
5.254	10.000	19.431	30.204	29.663
8h52.2m	19h23.3m	18h26.7m	18h52.1m	15h14.1m
18°01'	-22°07'	-23°37'	-22°04'	-2°34'

The Planets in Their Orbits



CCD Cameras: Digital Astrophotography is Here

The first wave of low-cost electronic imaging cameras is here and promises to be the most exciting thing to happen to amateur astronomy in the 1990s.

by Michael Chibnik



THE SPIRAL GALAXY M81 never looked so surrealistic as it does in George Fowler's false-color enhancement of a black-and-white CCD image. The exposure was a mere 30 seconds with a Photometrics Star I camera attached to a Celestron 14 telescope.

Amateur astronomy is about to undergo a revolution. Prices for electronic CCD imagers have finally come out of the stratosphere and dropped within reach of backyard astronomers. In the late 1980s, the average price for a CCD imager was over \$10,000. Today that price has fallen to \$1,000. Two examples of the new generation of CCD units are the model ST-4 from Santa Barbara Instrument Group and the series of Lynxx cameras from SpectraSource Instruments, though other companies are also introducing very capable and inexpensive CCD cameras. Just as they have changed the world of professional research, CCDs may also revolutionize the way many amateur astronomers look at the sky.

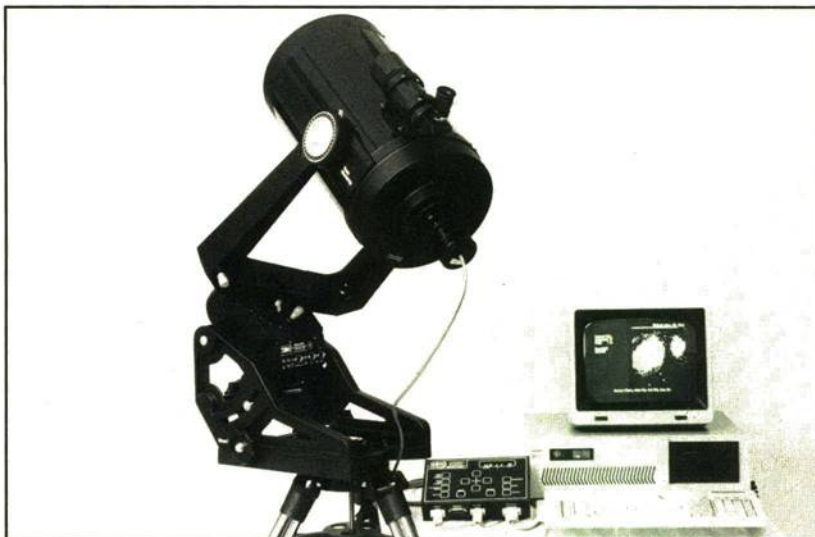
What's All the Excitement About?

CCDs (or Charge-Coupled Devices) are microchips that can turn light into a stream of digital data — electronic signals that can be recorded, altered, and displayed on a television screen. “Ah, ha! A video camera! I’ve got one of those already,” you might be saying to yourself. Not quite. While many of today’s home video cameras and camcorders use CCD chips, they are not capable of the level of performance that makes true CCD-imaging cameras so exciting. Home video camcorders are made for taking movies at 30 frames per second. Thus the longest exposure they can produce is 1/30 second. While some home video cameras can be very sensitive and very sharp, for astronomical uses they are limited to taking images of the Moon, planets, and bright stars. (See “Video Astronomy Comes of Age,” August 1990.)

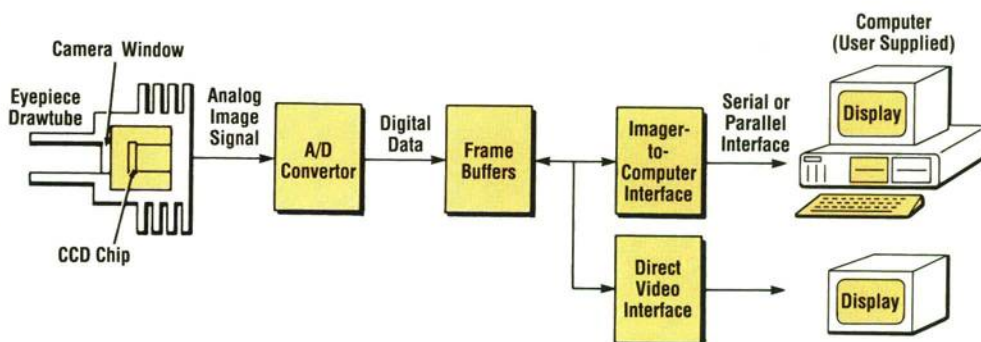
By comparison, CCD imagers like the ST-4 and Lynxx units are capable of exposures from 1/100 second up to 5 to 15 minutes (depending on the model). Just as with normal photography, longer exposures (or “integration times” in CCD jargon) allow you to capture fainter objects.

Deep-sky targets like nebulae and galaxies are within easy reach of CCDs. But long exposures with conventional film can photograph these kinds of objects, so why would one bother with CCDs? What’s all the excitement about?

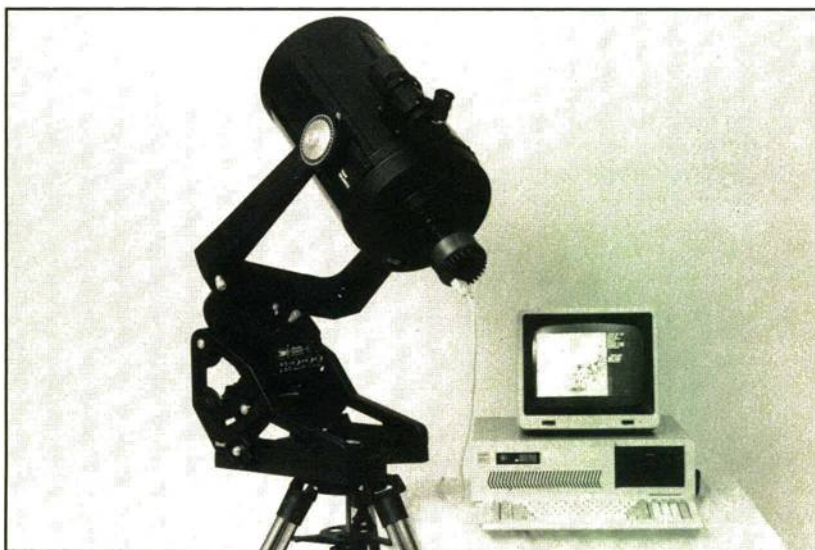
CCDs are attractive for several reasons. First, a CCD imager allows you to view the image almost immediately. Having an instant darkroom right at the telescope is immensely satisfying. If an exposure doesn’t turn out, you can discard it on the spot and simply take another.



THE ST-4 MODEL from Santa Barbara Instrument Group consists of the CCD camera head (attached to telescope) and a battery-powered controller (middle). You supply the computer (right) for image processing and storage.



MOST CCD CAMERA SYSTEMS consist of these basic components: a camera head with a controller unit that converts the image into digital data, plus a memory (called frame buffers) for temporary storage of images. Depending on the model, the controller either connects directly to a video display or connects to a computer for storing.



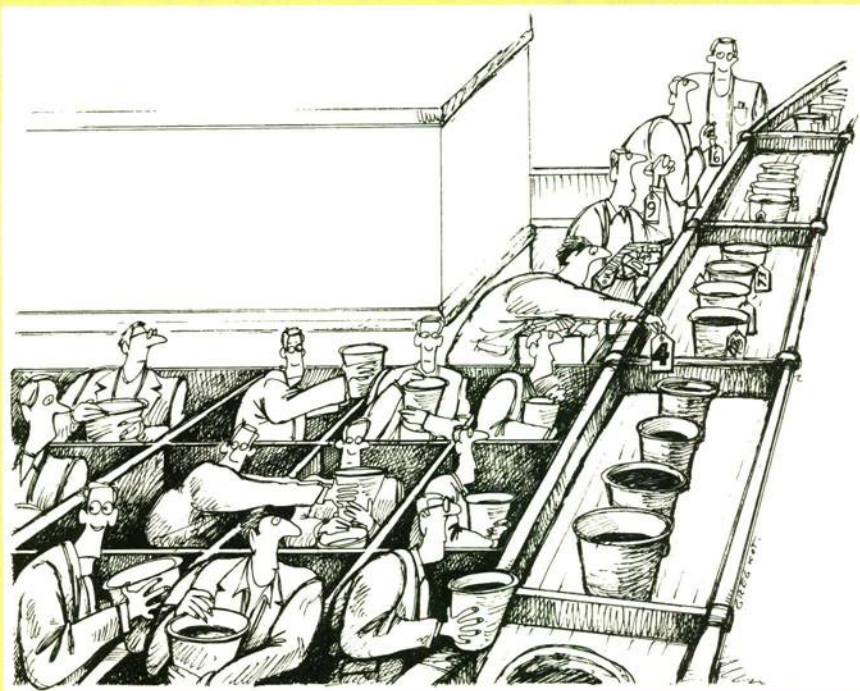
THE SPECTRASOURCE LYNXX camera (attached to telescope) comes in several models: a stand-alone unit with controller electronics, or, as shown here, one that connects directly to a plug-in card that you use with your own computer.

How CCDs Work (Sort of!)

A Charge-Coupled Device (or CCD) is an array of light-sensitive semiconductor elements. During an exposure, the incoming photons cause a build-up of an electrical charge on each of these picture elements, or pixels. In effect, the pixels act like tiny buckets collecting the electrons triggered by the light. At the end of the exposure, which can be anywhere from a fraction of a second to several minutes, the pixels are told "Empty your buckets!"

They do so in an orderly fashion, one row at a time. The first row of pixels hands its buckets of electrons over to a waiting series of bucket holders called "shift registers." Meanwhile, the electron buckets from the second row are all handed over to the first row, electrons from the third row are handed over to the second row, and so on. It's just like an old-fashioned bucket brigade.

Eventually, the buckets from all rows (anywhere from 192 to 1,000 or more rows, depending on the size of the chip) are passed across to the continually moving shift registers. The data-dumping process produces a single line of buckets marching into the CCD controller electronics where they are tagged with their position in the original array, and then stored. Each bucket also has



its contents measured, usually on a scale of at least 0 to 255, where 0 = empty and 255 = full. (For some cameras, it's a scale of 0 to 4,095.) Once all this information has been dutifully recorded by the bucket counters, the buckets can then be instructed to splash in correct sequence over a TV monitor to reconstruct a digitized version of the original image.

This leaves us with one question. If CCDs have tiny buckets of water in them, how can they work when they're chilled to -30° ?

The other advantage of CCDs over film is their incredibly short exposure times. Deep-sky objects can be recorded in seconds or minutes, rather than in grueling exposures of half an hour to two hours. It's possible to reach 16th- or 17th-magnitude stars in under a minute, and with a 6-inch telescope capture images of faint galaxy clusters that can barely be glimpsed in a 16-inch scope. The short exposures make it easier to guide (sometimes you don't even have to guide at all!) and you can take more images on those all-too-rare perfect nights.

The faster exposure times also work in your favor for taking better planetary images. With most films, high-resolution planetary images require exposures of $1/2$ to 10 seconds, long enough for atmospheric turbulence to smear details. If the image is bright enough, CCD imagers need exposures only $1/100$ second long, faster than a CCD video camera, and fast enough to freeze

fleeting moments of good seeing.

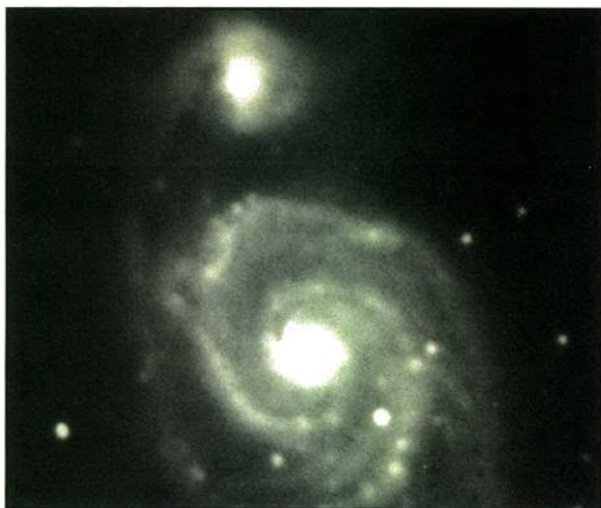
Faster Than a Speeding Electron

CCDs are fast because they are much more efficient than film at converting light into recordable images. For every 100 photons striking a CCD's surface, 40 to 80 are converted into a stored electrical signal. Film, on the other hand, squanders most of the photons that strike it. At best, even with ultra-fast ISO 3200 film, only 2 or 3 percent of the incoming photons react with the film's light-sensitive atoms to produce exposed film grains. If CCDs were a film, the typical imager would have a whopping speed of ISO 20,000 to 100,000!

In addition, CCDs do not lose their phenomenal speed over the length of the exposure. Film does. After 5 to 10 minutes of collecting light from a faint object, a fast film may have only a small fraction of its original speed. This flaw is called reciprocity failure and is the bane of every deep-sky photographer.

There are other selling points for CCDs. CCDs have a very low detection threshold — it takes only a few photons to trigger a flow of electrons. If an object is too faint, film won't respond at all. CCDs also have much less of a problem with saturation from overexposure — they will still show detail in even very bright parts of an object. (A classic case is being able to record both the central Trapezium stars and the faint outer tendrils of the Orion Nebula.) CCDs have consistent performance characteristics from exposure to exposure. With film, changes in humidity, temperature, age of the emulsion, and manufacturing lot number can all cause unpredictable variations in sensitivity. CCDs allow you to store images on regular computer floppy disks or hard disks that can be erased and used again and again. This is much less fuss than bothering with film hypering, chemicals, and processing.

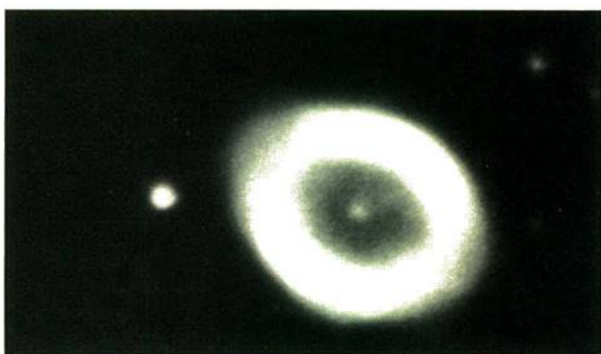
CCDs also lend themselves to pre-



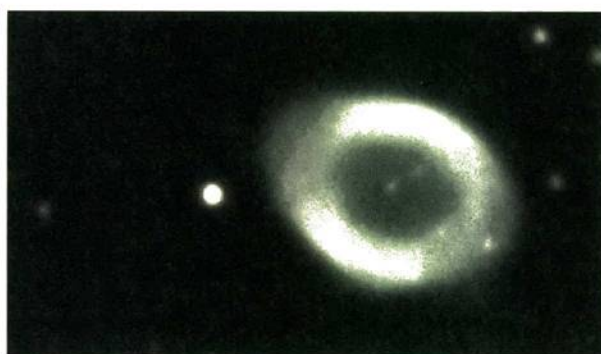
M51, THE WHIRLPOOL GALAXY, hypered 2415 film, 60-minutes, 11-inch SCT at f/7. Photo by Joseph Macrie.



M51, Patterson SS-700 CCD camera, 2 minutes, 8-inch SCT at f/5. Courtesy Patterson Electronics.



M57, THE RING NEBULA, hypered 2415 film, 31 minutes, 8-inch SCT at f/10. Photo by Jeffrey Jones.



M57, ST-4 CCD camera, sum of four 2-minute exposures, 11-inch SCT at f/10. Courtesy Santa Barbara Instrument Group.

SILVER HALIDE vs. **SILICON** is illustrated in these two pairs of images. CCDs have a narrow field and, when compared to film like Tech Pan 2415, have limited resolution. But CCDs require exposure times only a fraction of those needed by film.

cise measurement of data. This is the main reason they have become the standard technology for professional astronomical research. With the right software, it's possible to make accurate measurements of the angular separations between objects on a CCD frame. With the right filters, it's even possible to make accurate magnitude and color measurements of any star in an image, all at the click of a button on a computer. This is possible because unlike the response of film, the response of CCDs is linear: if an object's image has 100 times the density of another object's image, it is because it's 100 times brighter. This feature alone will appeal to many amateur astronomers who wish to get reliable data as part of their observing projects.

Some CCD cameras can also be used to guide your telescope automatically during marathon exposures with conventional film. The CCD camera is used in place of a guiding eyepiece and senses the motion of

the guide star. It then sends control signals to the telescope drive motors to keep the scope tracking the target with far greater accuracy than a weary eye and slow hand can. Even deep-sky photographers who prefer old-fashioned film for capturing images are finding that a CCD camera can still be a useful tool.

The Down Side of Downloading

CCD imagers do have their drawbacks. For one thing, they produce only black-and-white images. True color images can be produced only by taking three black-and-white images through red, green, and blue filters and then combining them electronically on a color monitor. However, most people will opt for adding color by assigning "false colors" to a single black-and-white image. That's how the color images in this article were produced. This level of image processing requires a computer with a high-resolution color monitor.

Besides producing only black-and-

white images, low-cost imagers like the ST-4 and Lynxx systems have other limitations that help keep them affordable. These imagers use a CCD chip that contains an array of 192 by 165 picture elements, called pixels. This is a relatively modest number. By comparison, premium units from companies like Photometrics, Western Research, and MicroLuminetics offer image areas of 384 by 576 pixels or larger, but at a much higher cost — \$4,000 to \$10,000. The four CCDs in the *Hubble Space Telescope's* Wide Field/Planetary Camera each measure 800 by 800 pixels, while the largest CCDs readily available today are 2,048 by 2,048 pixels and sell for \$60,000 apiece.

In both the ST-4 and Lynxx cameras, the 192 by 165 pixel array is contained in an area only 2.6 mm by 2.6 mm, less than 1 percent of the area of a 35mm film frame (which measures 36 mm by 24 mm). Because these chips are tiny, their field of view is very narrow. For example,

How To Talk CCD

Active Area — The physical size of the photosensitive array on a CCD chip. Low-cost chips are 2.6 mm by 2.6 mm. The biggest chips currently made are 60 mm square.

A/D (Analog to Digital) Converter — The part of a frame digitizer that takes the analog (continuous voltage) signal coming out of the CCD imager chip, measures the amplitude, and then assigns a numeric value to it. For an 8-bit A/D converter there are 2^8 values possible, yielding 256 discrete steps in gray tones. For a 12-bit converter there are 2^{12} values, or 4,096.

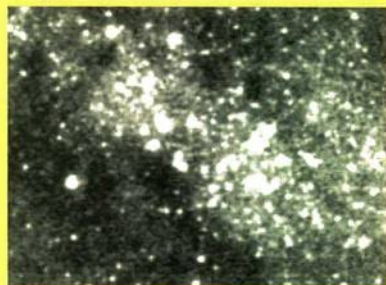
Bias Frame — A short, blank exposure that is subtracted from images to compensate for low-level bias current always present in a CCD.

Blooming — An effect caused when too much light hits a spot on a CCD imager. The voltage is too much for the charge bucket to hold and electrons spill into the adjacent locations, sometimes affecting an entire row of pixels, creating spurious lines. Most CCD camera manufacturers include special anti-blooming circuits.

Dark Current — Electrical noise generated by the internal circuits of the CCD chip. Dark current accumulates over time; the longer the exposure the greater the effect of dark current. Dark current can be minimized by cooling the chip and by mathematically subtracting an image of total blackness from the desired image of the object.

Dark Frame — The image taken of a black field that is used to determine the amount of dark current present, which is then subtracted from the main image.

Dithering — A technique for dis-



THE SMALL SAGITTARIUS STAR-CLOUD, SpectraSource Lynxx camera, 2 minutes, 135mm telephoto. Image courtesy SpectraSource Instruments.



THE EAGLE NEBULA, Photometrics Star I camera, 1 minute, 14-inch SCT. Image by George Fowler.

playing continuous tone images on non-gray scale monitors by using patterns of black and white pixels to simulate grays. The process is similar to the patterns of halftone dots newspapers use to print photographs.

Downloading — The process of sending the image data from the camera to a computer for enhancement or storage.

Flat Field — An exposure taken of a blank white area to "map" variations in pixel sensitivity. The desired image is then ratioed with the flat-field exposure to compensate for the effects of hot and dull pixels.

Full-Well Capacity — How many electrons a pixel can absorb before blooming sets in. Low-cost chips have a full-well capacity of 150,000 electrons per pixel. Better grade chips can absorb up to 500,000 electrons per pixel.

Half-Frame Mode — An operation in which the camera takes an image using only half the pixel array. It's faster than full-frame mode, takes up less memory, and is useful for focusing or for taking images of planets that do not occupy the full frame anyway.

Histogram — A graphical on-screen display of the number of pixels in each of the 256 or 4,096 brightness values.

Image Enhancement — The modifying of stored image data to remove defects or to make parts of the image more visible (or less visible). This is done by mathematically working on the image data pixel by pixel. You can alter contrast, filter out noise, and emphasize details.

Image Smoothing — An enhance-

ment that can reduce the effect of noise by making each pixel in the displayed image a weighted average of its own pixel value and the value of each of its eight neighbor pixels. This smooths or softens the image.



A LUNAR CLOSE-UP, SpectraSource Lynxx camera, 1/10 second, 8-inch SCT at f/10. Image courtesy SpectraSource Instruments.

Integration — An exposure with a CCD camera.

Micron — One-millionth of a meter. The pixels used in commercial CCD chips range in size from 13 microns to 25 microns across.

Pixel — The individual picture elements on a CCD chip. Pixels are arranged in a matrix of rows and columns.

Quantum Efficiency — The ratio between the number of photons entering and the number of electrons recorded. CCDs have a QE of 40 to 80 percent. Films have a QE of only 2 to 3 percent.

at the prime focus of an 8-inch f/10 Schmidt-Cassegrain, you can image an area only 4 by 4 arcminutes. With a telecompressor you can expand this up to 13 by 13 arcminutes. Nevertheless, compared to the Moon (30 arcminutes wide) or even some large nebulae or galaxies (the Andromeda Galaxy is 240 arcminutes, or 4°, wide), this field is small. On telescopes, CCDs are well-suited to capturing small objects such as galaxies, planetary nebulae, and compact globular clusters. However, simply finding your target and getting it well centered in such a tiny frame is more difficult than you might think.

For objects that require a wider field than a few arcminutes, you can put the CCD on a small, short focal length telescope (such as a fast 4-inch instrument — the sensitivity of the CCD makes up in part for the limited light-gathering power) or even a telephoto lens. In fact, for a field of view of 1° with an ST-4 or Lynxx camera, you need nothing fancier than a 150mm telephoto lens. A normal 50mm lens gives a field of 3°. This means you can use simple piggyback techniques to capture objects that with conventional film would require the focal length of a large telescope.

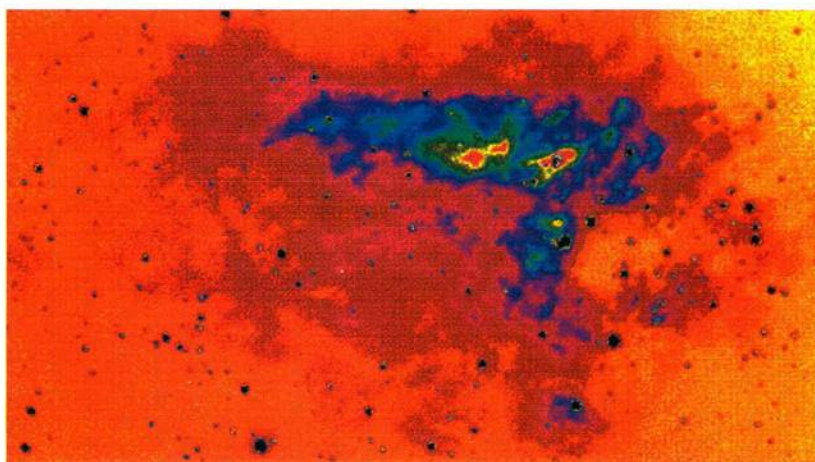
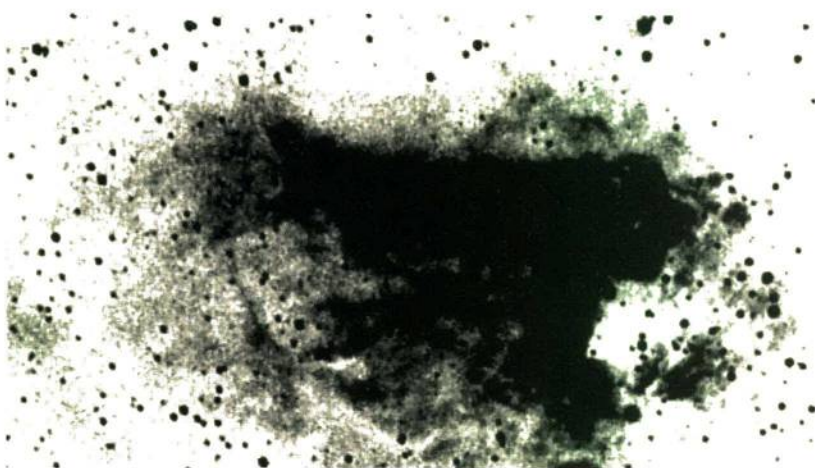
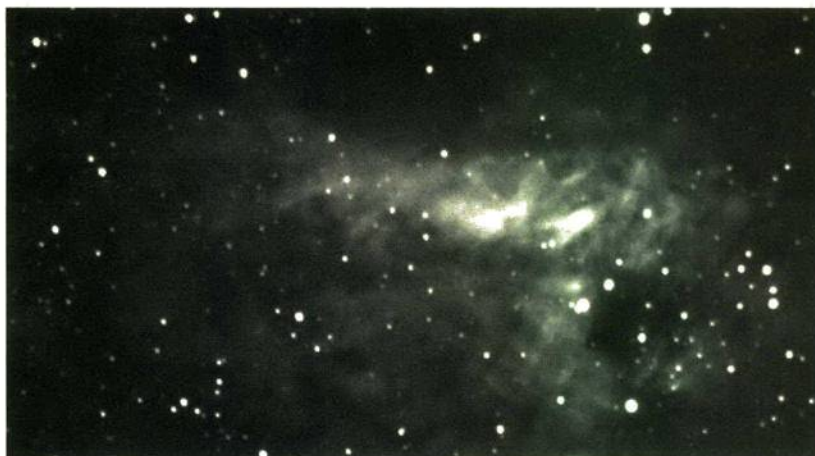
On the other hand, a 2,000mm focal length telescope like an 8-inch Schmidt-Cassegrain requires the addition of only a 2x or 3x Barlow lens and you are all set for taking frame-filling planetary images and close-up Moon shots. No need for eyepiece projection here.

However, the main caveat to CCDs is the complexity of hardware and computer software required for their use.

Anatomy of a CCD System

A typical CCD camera is by itself a fairly simple device. It consists of the chip securely mounted in a hermetically sealed case and protected by an optical window. The window keeps out not only dust but also moisture that could condense or freeze on the CCD's imaging surface. This is important because all CCDs designed for extended exposures must be cooled. The low temperature reduces a phenomenon called dark current, an internal, low-level electronic noise that without cooling would literally wash out the signal from faint light sources. The lower the temperature of the chip, the less dark current there is and the longer the exposure can be.

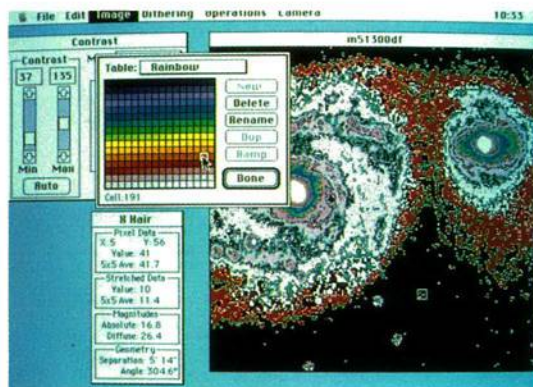
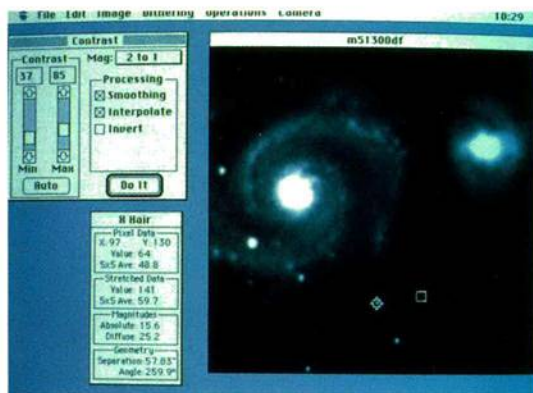
To reduce dark current, the low-cost cameras use solid-state thermoelectric coolers. Both the ST-4 and



THE BEAUTY OF CCD IMAGES is how easily they can be manipulated on a computer. The original image of M17 is at top. For the middle photo the image has been turned into a negative with enhanced contrast to bring out faint nebulosity. For the bottom image colors were assigned to the various brightness levels. Original image by George Fowler taken with a Photometrics Star I camera, 60 seconds with a 14-inch SCT.

Lynxx units reduce the chip's temperature to about 50° Celsius below the ambient temperature. When used at a normal room temperature of about +20° C, their thermoelectric coolers will keep the CCD chip at a chilly -30° C. This allows exposures

up to 5 to 20 minutes before dark current intrudes. By comparison, the more expensive imagers can chill the CCD to -80° C and sometimes use liquid coolants circulating through the camera. They can expose for up to one hour. Having to



A DIGITAL DARKROOM comes with most CCD cameras in the form of computer software that allows you to enhance contrast, convert images into negatives, and assign colors to various brightness levels. On some programs, you can also measure magnitudes and angular separations. The software shown here is for the Santa Barbara Instrument Group ST-4 camera.

cool a chip may seem inconvenient but a thermoelectric cooler is a luxury to use compared to the liquid nitrogen professional astronomers use to cool their ultra-sensitive cameras.

A CCD camera cannot simply be hooked up to a TV screen to display its image. To mediate between the two, you need "imager control electronics," otherwise called a frame digitizer. It takes the stream of data coming from the CCD and converts it to the right format for the video display. It also generates the signals that control the CCD — signals for exposures, image enhancements, focusing modes, etc. The controller is the part of the system that varies the most from one make and model of imager to another. Some models, like the Lynxx-PC and the Santa Barbara Instrument's ST-4, keep costs down by relying on the intelligence of a "host" computer that you must supply to do much of the video processing and camera control.

For example, the SpectraSource Lynxx-PC's control electronics are on a board that comes with the unit that you plug into your IBM PC or compatible. Similarly, the ST-4's control electronics are in a stand-alone unit that you connect to your computer (the ST-4 works with either a PC or a Macintosh) through a standard serial port, just like connecting a printer or modem.

With SpectraSource's top-of-the-line Lynxx models, a separate computer isn't necessary. Its imager control unit comes with enough smarts to manipulate and display images all by itself. It has a 16-bit microprocessor, enough memory (called frame buffers) for seven images, and a high-quality video monitor capable of displaying 256 shades of gray. However, if you want to permanently store and then manipulate images, you still need to connect this unit to a computer that you supply. There is no question about it — if you want to get into CCDs you need a computer.

The Computer Connection

There are other differences among the various models on the market. Once you complete an exposure, you need to download the frame and display it on your TV screen. To do this, some models (like the ST-4) communicate with their computers with what is called a "serial" interface. This type of connection is good for sending data over long distances (25 to 100 feet) but it is slow. Downloading a full frame can take 15 to 30 seconds. This can slow down the process of finding your target.

Cameras that use a "parallel" interface to your computer are much faster at displaying images, perhaps only 3 seconds, while units like the Lynxx-PC that use a board plugged inside your computer are faster still.

Most CCD cameras can record brightness values over a range of at least 256 steps (some divide the brightness range into 4,096 steps). To display any CCD image with photographic quality on a computer monitor, you'll need one capable of presenting a good range of gray tones. In the PC world, the best display is a monochrome VGA-class computer monitor. In the Macintosh world, it's best to have an 8-bit grayscale or color monitor such as the Apple Color Monitor. Monitors with lesser capabilities won't be able to display the full range of gray tones; images will lack smooth gradations from one tonal value to another. The worst displays are the low-cost CGA cards for PCs and the standard 9-inch monitors in the compact

Macintoshes and Mac Portable. They can display only two levels of brightness, either black or white. A software trick called "dithering" can help these monitors simulate true gray tones, but the results are far from satisfactory.

The need for a top-quality graphics card and monitor limits the usefulness of battery-operated laptop computers to control CCD cameras in portable setups. Laptops are excellent for verifying the capture of images and storing them, but the displays of most laptops limit their ability to present high-quality images.

A Digital Observing Session

All this technology can sound a bit daunting. But getting it working and producing top-quality images is part of the satisfaction.

You'll need a table near your telescope for the controller electronics, TV monitor, and your computer. Most of this gear will probably need 110 volts AC. While the Santa Barbara Instrument's ST-4 camera/controller happily works off 12 volts DC, displaying and storing images from it requires a computer which may need 110 volts AC, depending on the model.

The first step in capturing CCD images is to find your target. Before attaching the camera use a high-power eyepiece, perhaps with an illuminated reticle, to center the object of interest. A single bright star for focusing is the best object to start with.

Focusing is unusual because you can't look through a CCD camera. Instead, you must take a series of images, gradually tweaking up the focus each time. You could take a series of short-exposure, full frame images but the several seconds it takes to download each one makes for slow focusing. Instead, all CCD camera controllers can instruct the camera to take just a half-frame or quarter-frame exposure. You don't see as much of the image, but there's enough on the screen to tell whether the image is in focus. The download time is only one-half or one-quarter of the full-frame mode.

Once you are focused, replace the camera with the eyepiece. Don't touch the focus; instead re-focus the eyepiece by sliding it in and out. Mark the position of best focus with a marker or piece of tape. Now you can hunt for the object you want to record.

Despite the short exposures, the telescope still needs to be polar aligned. In addition, with a long focal length telescope such as an 8- to 11-inch Schmidt-Cassegrain you'll probably need to guide just as you

would for any deep-sky photograph. Once you complete the exposure, the control software automatically downloads it to the temporary storage of a frame buffer in the camera controller.

But before you can display the image at its best, you need to take what's called a "dark-frame" exposure. This image is equal in length to the exposure you just made. To take a dark frame reading with the Santa Barbara Instrument unit, you literally put the lens cap over the top of the telescope. The SpectraSource Lynxx units have a built-in shutter. The control software downloads this dark-frame into another frame buffer and electronically subtracts it pixel by pixel from the first exposure. This subtracts thermal "noise" from the data and makes for a cleaner image. For even better image quality, you should also subtract a short "bias-frame" exposure to compensate for the low level of bias current always present in a CCD. Finally, take a "flat-field" exposure. This is a short exposure of a blank white field that maps small pixel-to-pixel variations in sensitivity.

Your Digital Darkroom

The biggest advantage of electronic images is how easily they can be manipulated. All the CCD cameras come with software that allows you to instantly change the brightness and contrast of the image. A good way to do this is to call up what's called the "histogram mode" on the computer screen. The histogram is a graph that shows you how many pixels have a particular intensity level. Looking at this display helps you stretch or compress the range of tonal values.

For example, you can "stretch" an image by taking only those pixels that fall within a narrow range of intensities, say from level 100 to 150, and then making the dimmest pixels appear much blacker than they originally were and the brightest pixels appear much whiter. This is like boosting contrast on film. Enhancing low-contrast planetary features is one application. You can also shift the range of displayed values up or down by a fixed amount. For example, any pixels below a certain value can be ignored and displayed as black, a good way to eliminate noise and sky fog.

For this kind of image work, it's helpful to have as many brightness steps in the original image as possible. Cameras that have what's called "12-bit" resolution produce 4,096 gray levels (as opposed to the maximum of 256 levels from an "8-bit"

CCD Camera Suppliers

Astro-Link; P.O. Box 1978, Spring Valley, CA 92077; (619) 449-4722.

Catenary Systems; 470 Belleview, St. Louis, MO 63119; (314) 962-7833. Image processing software for the PC.

ELECTRIM Corporation; P.O. Box 2074, Princeton, NJ 08543; (609) 799-7248. Astronomy image-enhancement software available from TRIFID Corporation; 744 Office Parkway, Suite 224, St. Louis, MO 63141-7128; (314) 991-3095.

Micro Luminetics, Inc.; 3447 Greenfield Avenue, Los Angeles, CA 90034; (213) 839-0690; FAX (213) 836-4733.

Patterson Electronics; 360 East First Street, Tustin, CA 92680; (714) 544-4127.

Photometrics Ltd.; 3440 E. Britannia Drive, Tucson, AZ 85706; (602) 889-9933; FAX (602) 573-1944.

Prime Focus Imaging; 128 Elpis Road, Camden, NY 13316; (315) 245-3596.

Santa Barbara Instrument Group; 1482 East Valley Road, Suite 601, Santa Barbara, CA 93108; (805) 969-1851; FAX (805) 969-0299.

SpectraSource; P.O. Box 1045, Agoura Hills, CA 91376-1045; (818) 707-2655; FAX (818) 707-9035.

Western Research Company, Inc.; 2127 E. Speedway, Suite 209, Tucson, AZ 85719; (602) 325-4505.

camera). Isn't this technical overkill? After all, why bother with so many brightness levels if, as is the case with most computer monitors, you can display only 256 levels? The benefit of 4,096 gray levels comes when you select only a narrow range of them and stretch the contrast. If the brightness range you're trying to enhance is divided into a finer series of steps, your final enhanced image is more likely to retain a smooth gradation of tones. Extreme stretching of an image produced by an 8-bit resolution camera will create a noticeable stair-stepping of brightness levels, giving the image a distinctly digital look.

In addition to contrast manipulations, you can turn the image into a negative, flip the image horizontally or vertically, or zoom in on small sections of the object. To reduce noise, you can electronically add several images together, the CCD equivalent of integration printing. You can even electronically eliminate the fogging from light pollution or moonlight. All this can be done before you finally save the image or afterwards at your leisure on those cloudy nights. Your home computer becomes your digital darkroom in a wonderful marriage of astronomy, photography, and home computing.

You can even share your images with other CCD fans the way you would any computer files, either by swapping disks or by transmitting your files by modem. (In fact, some of the images in this article were sent to ASTRONOMY as image files on disks.) CCDs will give astronomical

computing an entirely new range of possibilities.

Are They For Everyone?

CCDs are exciting. But they aren't for everyone. They will appeal to portions of the amateur astronomical world: those people who want to experiment with state-of-the-art imaging, deep-sky observers chasing the ultimate challenge objects, those who wish to make measurements of positions and magnitudes, and those who find satisfaction in combining an interest in computers with an interest in astronomy. Low-cost CCD cameras provide amateur astronomers with yet another incredible tool for exploring the sky. The best thing about CCD cameras is not how well they can do things we have already done, but what new vistas they'll open up. Over the next few years CCDs will give the hobby a new direction. It isn't a direction everyone needs to go, but it's a direction that gives us all another exciting way to enjoy astronomy. □

Michael Chibnik is an electronics engineer and president of the Ventura County Astronomical Society in California. His last article was "Video Astronomy Comes of Age," August 1990. The author and the editors of ASTRONOMY would like to thank Richard Schwartz of Santa Barbara Instrument Group, Steve McArthur of SpectraSource Instruments and Burt Beardsley of Photometrics Ltd. for their generous loan of equipment and assistance in the preparation of this article.

Update On The SCT



Meade has focused intensive efforts on delivering top quality in telescope electronics, mechanics, and optics.

by Richard Berry

What does a telescope buyer want? That's a question that Steve Murdock thinks about a lot these days. Murdock is vice president of Meade Instruments Corporation, and the man who spent the better part of two days answering my questions when I visited Meade's factory last April. Murdock ponders factors like portability, attractiveness, versatility, and application for photography. Today Meade is developing many new products to serve amateur astronomers, and the future looks bright.

The last two years were tough sledding for Meade. Telescope sales began declining in mid-1989 for various reasons: market saturation, a general slowdown in the economy, and flagging consumer confidence. Telescope sales fell significantly in 1990.

Enter Ira Herman, the new president of Meade and a man with a mission. "We embarked on a continuous quality upgrade program in May 1989. Our aim is to progressively make our telescopes better and better, right down to the last nut and bolt."

Ira Herman is still new to the telescope industry, but he brings important lessons from the manufacture of another high-tech product: computer hard disk drives. "Zero defects" is nothing new for Herman because nothing less is acceptable in hard drives. And for Ira Herman, nothing less is acceptable in telescopes.

"Around here I talk a lot about quality," Herman told me, "and the good thing about your magazine's reviews is that they justified my position." Because Herman was most

familiar with electro-mechanical systems, he first focused his efforts on the electronic and mechanical subsystems in Meade's telescopes. He has since become a champion of first-rate optical performance, too.

Terry Ostahowski heads the optical shop at Meade and is directly responsible for the optics that go into every Meade telescope. With him I toured the shop where mirrors and corrector plates are made.

Each primary mirror begins life as a molded blank of low-expansion glass. Ostahowski's opticians quickly grind the precise curve into the front surface, checking for depth, and then polish it. Opticians also polish secondary mirrors for the Meade 2080 into smooth spheres. "Our aim," Ostahowski said, "is to get an extremely accurate sphere on the primaries and



BENDING INTO HIS TASK, optician Phil Moniot completes final work on precision optics by hand.

SEVEN GLASS BLANKS await grinding. They will become secondary mirrors for Meade 8-inch SCTs.

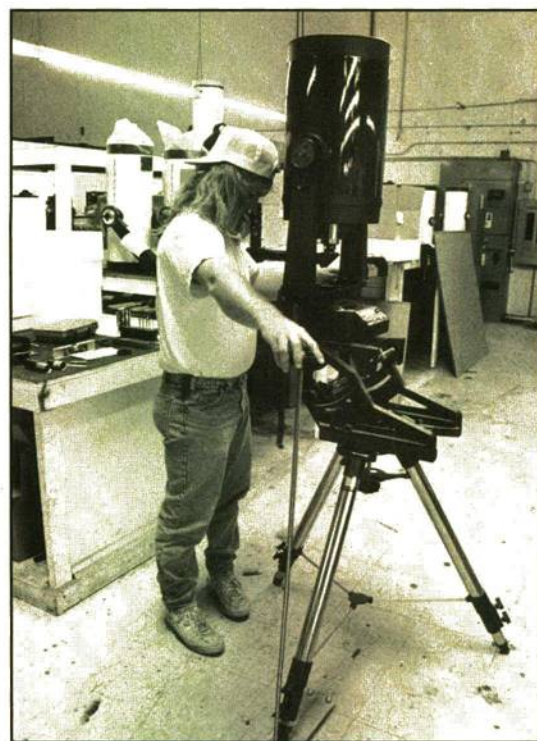
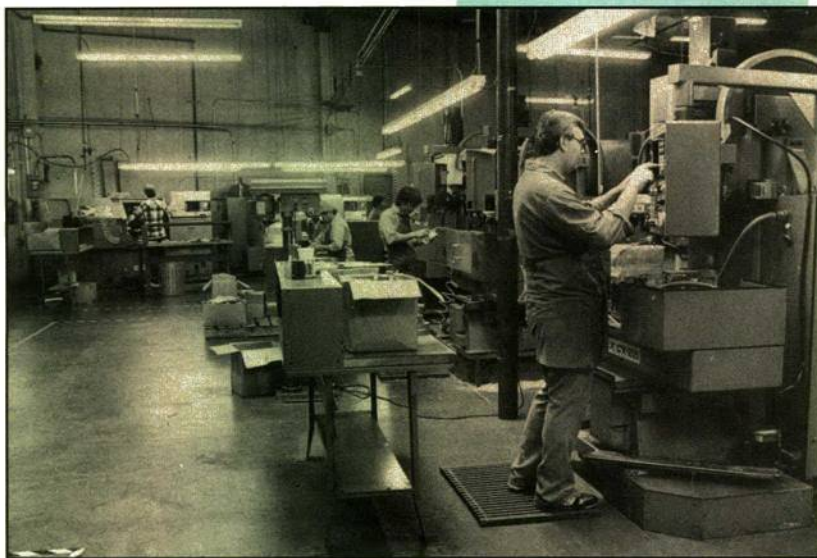
to reduce variation in the secondaries as much as possible."

For Meade the optical "magic" takes place in figuring the corrector plate. Opticians in the production room mount thin glass corrector blanks in airtight holders and pump out part of the air behind the glass. The glass bends slightly inward in a curve called a catenary. After each side of the glass has been polished, the glass — now with the complex

"donut" curve of a Schmidt corrector on its surface — is tested.

Ostahowski checks every corrector plate coming from the shop in a master test jig. Figuring the corrector plate directly gives Meade's SCTs very smooth figures; the tricky part for

MEADE'S MACHINE SHOP
produces the hundreds of small
precision components that go
into every telescope.



ALIGNING THE MOUNT for Meade's top-of-the-line Premier Series calls for numerous painstaking adjustments.

DON ("BIG D") JACKSON assembles and orients the optics of hundreds of 90mm Meade telephoto lenses.



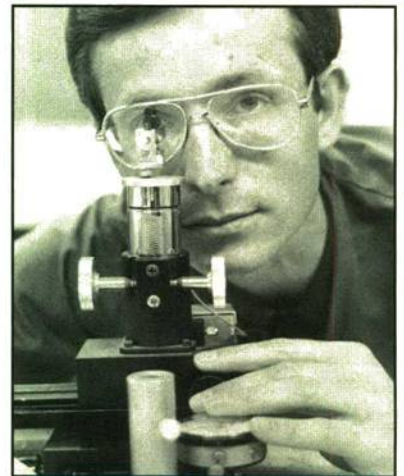


THE OPTICAL TEST JIG checks every mirror. Chief optician Terry Ostahowski inspects Model 2045 mirrors.

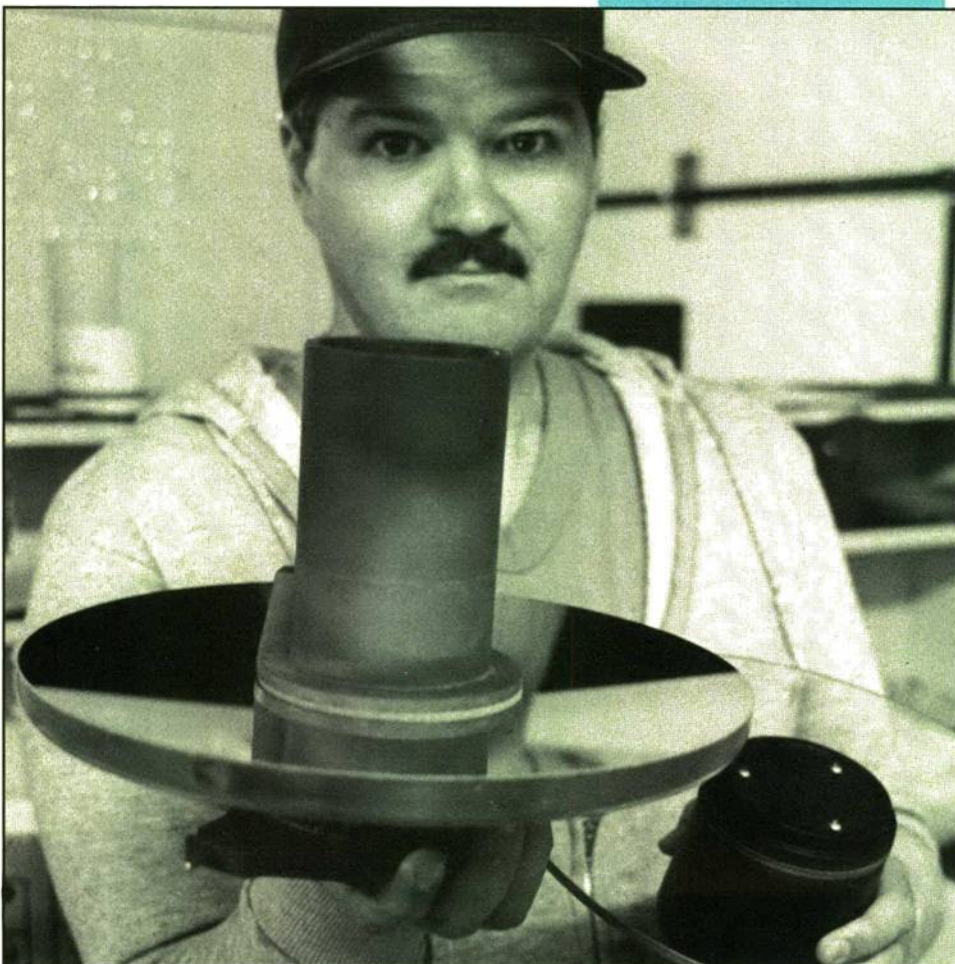
MATCHED OPTICS are ready for assembly and testing in a telescope. Shown is the 10-inch f/6.3 optics set.

the optician is controlling the depth of the donut. Imagine the depth of the donut as the thickness of a 500-sheet package of paper: take one sheet off the top, he would find it acceptable — but take two sheets off and Ostahowski would reject it!

When a corrector is close to perfect, it goes to Ostahowski's matching room, where he pairs each corrector with a primary and secondary. In theory, he said, any corrector will match any primary and secondary, but in practice, he pairs a "hot" corrector with a "cool" pair of mirrors, or vice versa, to balance each set of optics.



THE KNIFE-EDGE TEST allows Phil Moniot to figure parabolic mirrors to within a few millionths of an inch.



A PERFECT FIT before the tube components are sent for anodizing and painting guarantees smooth focusing.

"We transfer a bad set of optics to the assembly area once in a while," said Ostahowski, "but not very often. They're tested again when they're assembled in Steve Burkholder's area, then later with the Ronchi and diffraction ring tests. At every stage many people have the authority to send a system back for rework. The bad ones just don't get through."

One strength of Meade's quality assurance program is that employees understand they are responsible for Meade products. "When complaint letters come in," said Herman, "I send copies to manufacturing so they remember there are real people out there using these products."

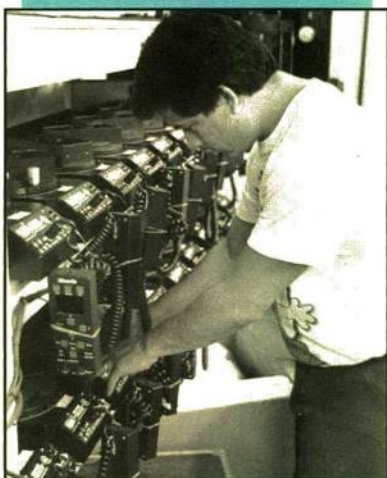
Steve Burkholder, supervisor of

Meade's Schmidt-Cass telescope assembly area, told me, "Assembling the optics can be very time-consuming. I'll work with all three elements until I get the best possible image — not just an acceptable image, but the absolute best. We check every telescope with a 4.7mm wide-angle eyepiece and a 2x Barlow."

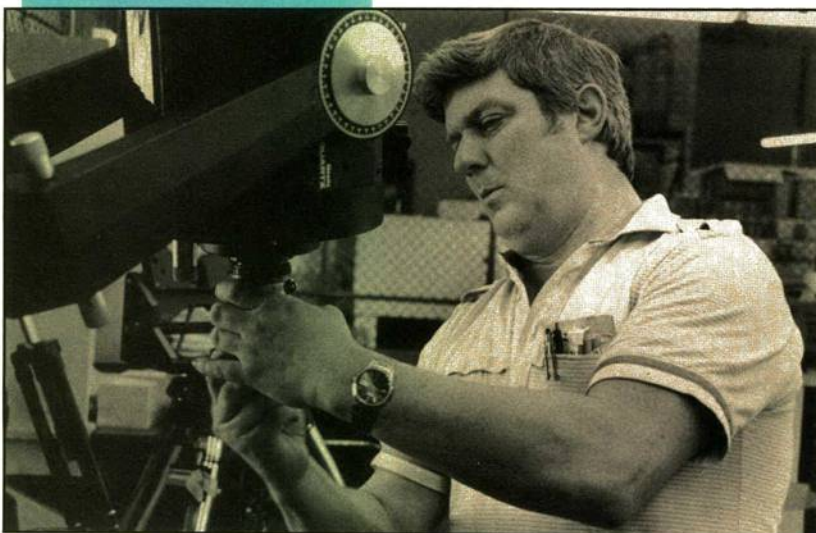
Burkholder's telescope builders assemble each optics set in special cut-away telescopes with large holes in them so they can reach into the tube to align and rotate the optics. The "cutaways" are aimed into Newtonian telescopes outfitted with artificial stars — tiny ball-bearings lit with an intense beam of light.

I looked through three telescopes being built; two of the telescopes formed excellent images of the artificial star. Burkholder warned me about the third: "This one's not right yet. We'll try a different secondary to see if we can't get a better image. As it stands, this one's not good enough." I would have rated the reject scope a B+ on ASTRONOMY's testing scale.

A 24-HOUR BURN-IN TEST catches faulty telescope electronics and drive motors before they leave the factory.



THE BUCK STOPS HERE with Ben White, the quality control man. "We test every part and every function."



FINDING THE REASON a part doesn't "make spec" and eliminating the problem is the goal of quality control.



A set of optics that fails to meet Burkholder's standards goes back to Ostahowski's optical shop for reworking. "As long as it doesn't get out the door, I don't mind taking back work," said Ostahowski, "but I want our customers to see nothing but our best work."

Assemblers carefully mark good optical sets for position, then mount the primaries on slider assemblies and put the secondaries and corrector plate assemblies in place, securing them with a rubber adhesive. When the adhesive has cured fully, the crew installs the optical set in a telescope tube and checks it again. "If anything has a problem, we nail it here," Burkholder said.

But the checking is not over yet. Every telescope leaving the factory must pass muster with Ben White, the final step in Meade's quality assurance. White gives every telescope a rigorous 49-point mechanical and electrical check.

"We really work 'em hard," said White, "with an absolutely worst-case test. We put the scope on a highly tilted mount, hang a five-pound weight on the rear, give it 11.5 volts instead of 12 volts, and put it through all its paces. Every single base gets tested for every single function. With drive motors, anything but a nice smooth hum and the scope is back at mechanical."

"Our goal is zero defects," said Ira Herman. "We're almost down to zero now," added White.

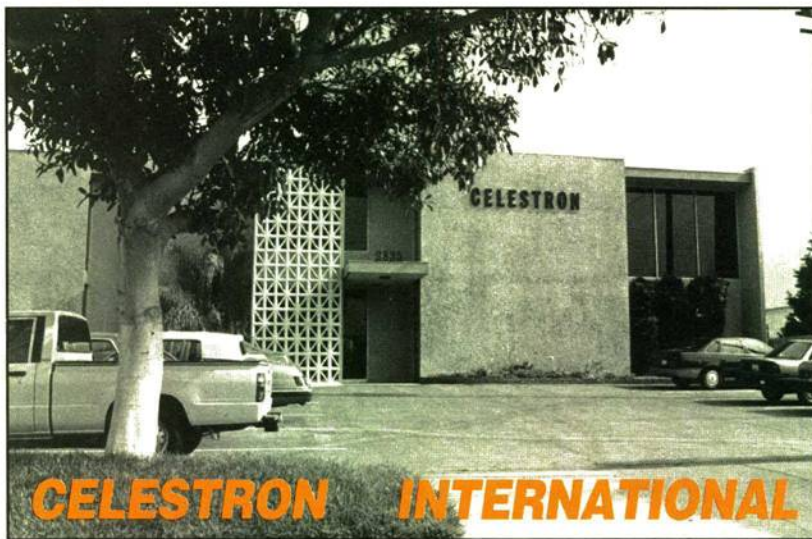
Steve Murdock, Ron Ezra (Vice President of Engineering), and the marketing and engineering staff at Meade constantly search for new ideas. Rob Wood, the "creative" project engineer, turns ideas into products. To his credit are Meade's Superwedge, the new designer series Meade 2045, and the new PPEC drive system.

"I'm proud to be working at Meade," said Wood, "because people who see our products say, 'Wow, that's really neat!' In design I want not one question unanswered, not one thing less than excellent."

Added Herman, "Fundamentally, I want Meade to be the dominant telescope company because we offer the best value to the consumer and first-rate quality is what will make the difference for us — quality and consistency."

At Meade, I was impressed by the effort employees put into their telescopes. From customer service to final sign-off for Ben White, they consistently exhibit their strong concern for the product, for its quality, and for the consumer. □

Update On The SCT



Celestron has focused on making quality optics and meeting customer needs.

by Richard Berry

At the core of Celestron's planning and production lies the consumer. "The products we develop today," says Alan Hale, president of Celestron International, "are the products we know the market wants. We listen to consumers, dealers, and distributors."

This marketing philosophy arose following the crisis in telescope sales after the apparition of Comet Halley. Celestron misread the market, Hale told me, as did most manufacturers and importers. Grossly inflated projections of telescope sales — part of Halley-mania — had dazzled the marketing experts. Company management demanded a four-fold increase in production to meet the anticipated sales.

But while Halley produced excitement, it didn't produce telescope

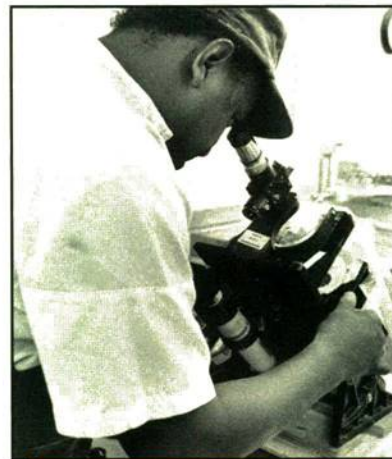
sales as anticipated. As the comet approached, dealers placed orders for hundreds of telescopes. When they did not sell as promised, dealers canceled their orders, leaving telescope manufacturers holding the bag.

"In 1985 we were running the shop twenty-four hours a day, six and seven days a week," said Jim Cordray, vice president of operations, "but we couldn't keep up. We wore out the machines and the workers. When the telescope market crashed in '86 we were forced to lay off most of our work force, leaving us with only a skeleton crew. Capacity, as well as quality, had slipped."

Celestron was also left with unsold C8s in inventory. One of Hale's first actions as Celestron's returning president in early 1987 was to shut down the plant and repair the damage.

Today, under Alan Hale's direction, Celestron is devoting itself to building a reputation, building up production, and building in quality. In May I spent two days at Celestron's plant in Torrance, California, talking to Celestron employees. Rocky Cimarusti, the head of optical production, best stated the feeling at Celestron: "It was a crushing thing for us to know that our quality suffered so much during those years. But we've remade our optical masters, we're producing telescopes, and we're making a first-rate product."

Producing a Celestron telescope begins with the molded glass blank that will become the primary mirror. After opticians have roughed out the blank on a curve generator and ground it on fast-cutting diamond pellets, they polish the glass disk and



OPTICAL SHOP WORK, even for small scopes like the C90, requires checking at every stage of production.

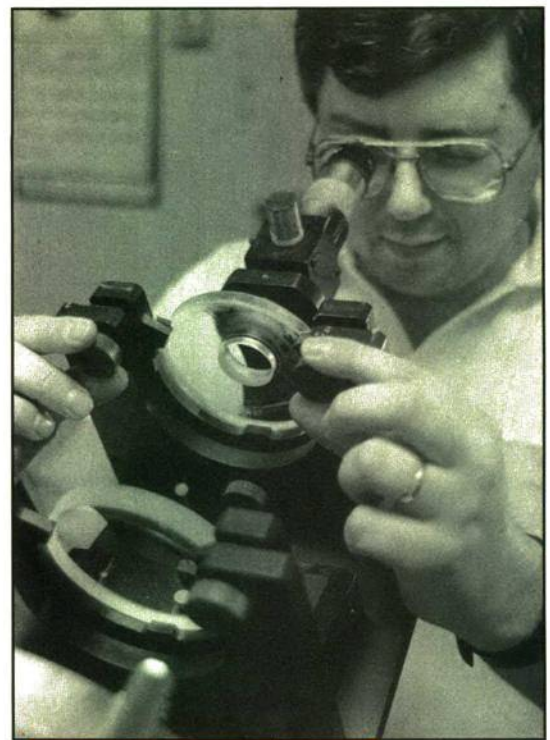
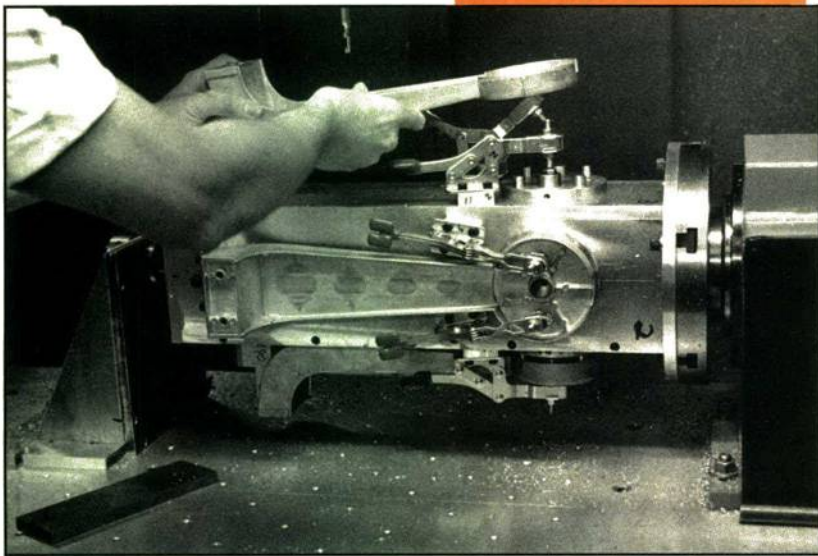
THIS GLASS BLANK will become a precision telescope mirror under the direction of Rocky Cimarusti.

then test it. To pass muster, the curve must meet depth specifications within 0.0002 inches and be close to a perfect sphere. The mirrors are easy work for opticians, and familiar.

Corrector plates are a different matter. The proper figure for a corrector is a complex curve that is high in the center, deep in the middle, and high again at the edges — a “donut” profile. Before Celestron’s time, corrector plates cost tens of thousands of

dollars to make and demanded hours of work from skilled opticians. Celestron’s founder, Tom Johnson, revolutionized the manufacture of corrector plates for Schmidt-Cassegrains with a simple and elegant technique (that is patented).

FOUR AT A TIME, aluminum castings are machined to dimension on a high-speed, numerically controlled mill.



TESTING HIS WORK keeps optician Mark Martinez on his toes. Opticians test each mirror after it is made.

RANKS OF MACHINES whirl ground blanks into telescope mirrors in a bath of polishing fluid.





THE SECONDARY MIRROR is the key to Celestron's optics. This mirror corrects small residual errors.

PRECISE CONTROL produces corrector plates that compensate for the spherical aberration of the SCT primary.

Celestron's opticians place thin glass disks against precisely shaped master blocks. Vacuum pumps remove the air between the disks and the masters, so the disks bend and conform to the shape of the masters. The opticians then polish the reverse side of each disk flat. When they release the vacuum and take the disks off the masters, each disk has a reversed replica of the master's profile.

Rocky Cimarusti monitors the production of corrector plates with a special test apparatus. He slips each plate into the tester — a correctorless C8 telescope — and spins it, looking for irregularities.



VACUUM COATING makes glass into bright mirrors. Helene Paros prepares materials for the next coating run.



BRIGHT MIRRORS sport layers of oxide and aluminum to reflect more than 95 percent of the light striking them.

"I check for everything," said Cimarusti, "striae in the glass, ripple, what we call 'meatballs' that come from bad contact, warping, zones, uniformity of polish, and total correction." Working closely with a single worker who monitors the glass, laps, blocks, and processing, Cimarusti fine tunes the demanding process of deforming glass until corrector after corrector pops off the blocks meeting specification.

But secondary mirrors are the real key to optical production. Workers grind and polish the raw glass on small lens-making machines and send them to the optical lab where a cadre of opticians imparts the optical *coup de grâce* — zeroing out a set

of telescope optics by hand-figuring the secondary mirror.

Steve Kennedy, one of the elect who work the secondaries, explains: "We fix up any errors that remain by figuring the secondary. Total correction, zonal irregularities, up or down edge on the primary, holes or bulges in the corrector — all that we can fix. A good Airy disk is our goal. In this room we figure out what we have to do to make the image good."

Cimarusti added, "The company has tried to eliminate hand correcting because it's time consuming and very expensive. But there are too many variables, and we've never managed to achieve it. Today's optical machinery can't hold precise enough tolerances. If it were easy, making optics would just be bing-bing-bing, but optics aren't easy."

"Every system that comes into the lab starts with a complex mix of errors," optician Mark Martinez declared, "so we tackle the main things first. Step by step we clean them up. Then we finish with a clean-up run."

In the optical lab each set of optics is also carefully "rotated" to an optimum position. "Rotation can be just as important as the hand correction," Kennedy explained. "It's something you develop a sixth sense for. In working with optics I've developed some superstitions, and I'm a logical and rational guy."

Certified by the optical shop, the optics go for aluminizing and overcoating. Helene Paros is proud of the skill she's developed in coatings: "We've been fine-tuning our coating process for years and have it about as good as it can get. Other vendors say they can't even touch us." With multi-layer "stacks" of metal oxides, Paros builds the 88-percent reflectivity of bare aluminum to an astonishing 96 percent in the large vacuum chamber. "We're getting excellent batch-to-batch consistency," Paros added as she checked the tungsten filaments and refilled oxide boats in the coating chamber.

The last stop for any telescope after assembly and before it is shipped is Alphonso Carbajal's quality-control station. Carbajal's eyes glimmered in the beam of collimated laser light that crosses the small, darkened room where he works. "I check the optics here," Carbajal said, pointing to a tight red spot of laser-simulated starlight on a screen beside him. He also checks the mechanics of the declination slow-motion control, the cosmetics of the paint and finish, and, in a new test, he checks the smoothness of the clock drive.

"This area is here to catch problems before they cause trouble," said Carbajal. "Orientation errors can cause astigmatism and the wrong secondary can give gross spherical aberration. If there's any kind of production problem developing, we nip it in the bud."

Back in Alan Hale's office, Hale spoke about Celestron's future: "My goal is to redo our entire line, to gradually upgrade or replace our current product line with better products, and to upgrade our accessory line. That takes time. We decided two or three years ago to add our periodic error corrector. It's just coming out now."

Hale exudes confidence and a strong sense of Celestron's mission. "We serve a large community of Celestron owners out there," he states, then adds "and we're also here to make astronomy affordable for the average person on the street."

"Philosophically speaking, we know where Celestron is headed. The market as well as the critics have noted our progress. Our direction seems to be right." □

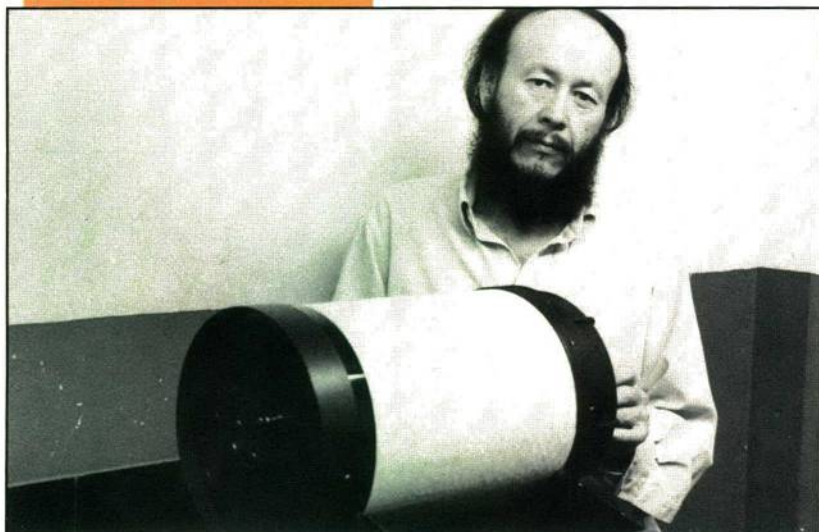
A C11 TAKES SHAPE in the main assembly area. This secondary and corrector will next be inserted into a tube.



THE EAGLE EYE of quality control inspector Alphonso Carbajal catches optical systems that don't make the grade.



ONE LAST TEST before being shipped from the shop verifies that this optics set forms round star images.



Galaxies of the Great Square

The Great Square of Pegasus holds some of autumn's most unusual and challenging galaxies for small telescope observers.

by David Higgins

The Great Square of Pegasus forms part of one of the most recognizable constellations in the autumn sky. Located far from the obscuring bands of dust and gas in the Milky Way, Pegasus is loaded with galaxies. Although not as well endowed with large or bright galaxies as its neighbor, Andromeda, Pegasus does provide a wide range of challenging objects to keep you busy on these cool nights of autumn.

Within the borders of the Square of Pegasus lie galaxies with some of the largest and smallest NGC numbers around. This results because the 0h line of right ascension passes through the constellation. Unfortunately these galaxies are not the brightest in the NGC nor are they the easiest to find. However, the galaxies of Pegasus offer an exceptional challenge for users of small telescopes. Spotting the galaxies within the Great Square will test your observing ability and the darkness of your sky. Can you find four of these galaxies? Six of them? Ten? The more of these distant spirals and ellipticals you record, the sharper your eye and keener your observing ability.

Gamma (γ) Pegasi anchors the southeastern portion of the Square and it is here that you will find the constellation's largest and brightest galaxy. **NGC 7814** is an edge-on spiral galaxy that measures 6.3' by 3.2' and glows at magnitude 10.5. This galaxy shows a great amount of detail in small scopes.

NGC 7814 is located slightly more than 3° northwest of Gamma Pegasi, just a couple of arcminutes southeast of a 7th-magnitude star. The galaxy's elongated halo is extended northwest-southeast. A 4-inch scope shows this halo as an oblong glow with no apparent brightening toward the center. The middle of the galaxy is a little thicker compared to the edges. You won't need averted vision to see this edge-on spiral so don't be afraid to increase the magnification.

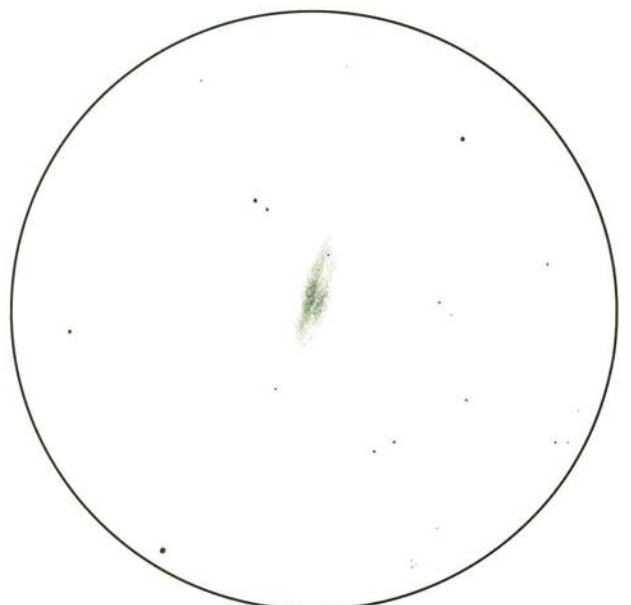
In larger scopes NGC 7814's core appears condensed and lies just south of a faint field star. At high magnification you will see a slender dust lane that bisects the galaxy. The northwest and the southeast portions of the dust lane are the easiest to see; to spot the entire length of the dust lane requires a night of excellent seeing.

In 16-inch telescopes NGC 7814 takes on a different appearance. The dust lane becomes visible across its entire length and the core becomes much brighter. The faint field star to the north of the core is easily visible. Curiously, some observers have sighted the dust

lane with scopes in the 4-inch to 6-inch range, while others with larger scopes have not mentioned seeing the lane. What you will be able to see depends on the size of the telescope you are using, how well it is collimated, your observing site, and the sky conditions.

About 1° south of Alpha (α) Andromedae lies a most interesting group of galaxies. One of the most attractive objects in the group is **NGC 1**, the first object in J. L. E. Dreyer's *New General Catalogue*. In a 4-inch scope NGC 1 appears like an oval spot glowing dimly at magnitude 13.4. This open-armed Sb-type spiral measures 1.9' by 1.5' and, like many of the galaxies in this region, has a rather low surface brightness. NGC 1's core is visible only with averted vision using scopes in the 6-inch to 8-inch range. Larger scopes provide a marginally better view, making the galaxy's core somewhat easier to disentangle from the outer envelope of haze.

Several arcminutes south of NGC 1 lies **NGC 2**, another of those small-number NGC galaxies that suffers from low surface brightness. NGC 2 measures 1.4'



NGC 7814
Sketch by D. J. Eicher 17.5-inch f/4.5 reflector at 213x



NGC 7814
Mag. 10.5 Size 6.3' by 3.2' by Kim Zussman



NGC 1, NGC 2, and NGC 16
Mags. 13.4_p, 14.8_p, and 12.0 Sizes 1.9' by 1.5', 1.4' by 0.9', and 2.1' by 1.2' by Joe Liddell

by 0.9' and at 14.8 magnitude requires averted vision. In small scopes it is a faint oval haze with no central brightening. Larger scopes of course give a brighter view but do not provide much improvement overall.

About 30' east of NGC 1 and NGC 2 and 1.5° south of Alpha Andromedae lies the much brighter galaxy **NGC 16**. Glowing at magnitude 12.0 and measuring 2.1' by 1.2', NGC 16 is an easy target for small telescopes. A 6-inch instrument shows NGC 16 as an oval haze with no central brightening. In a 10-inch scope NGC 16 is oval but the core appears much brighter than in the 6-inch view. Large scopes show a stellar nucleus and a bright haze surrounding the core.

While you're in the area, drop about 2° southeast of NGC 1 and NGC 2. There you will find **NGC 23**, a 2.0' by 1.9' spiral that glows at magnitude 12.0. Much brighter than its northerly neighbors, NGC 23 is easily visible as an oval elongated north-south in a 6-inch scope. A 12-inch scope shows a stellar nucleus and crisply defined edges about the galaxy's perimeter. At first glance NGC 23 appears to have a double core, but on closer inspection you will see a faint field star located about 20" east of the galaxy's center. When you're finished with NGC 23, nudge your scope about 10' southeast and try **NGC 26**. This 14th-magnitude spiral is difficult for 6-inch scopes but telescopes in the 12-inch range reveal its oval shape.

About 1° north and a little west of 81 Pegasi lies a

little trio of galaxies. **NGC 7769** is the brightest of the three, glowing at magnitude 12.1. This Sc-type galaxy measures 1.8' across and appears as a round disk in small scopes. Telescopes in the 12-inch range show the core brightening ever so slightly toward the center and the galaxy appears slightly elongated east-west. Scopes in the 17.5-inch range present a little different view. The core appears stellar and the haze that surrounds the nucleus is much better defined.

East-southeast of NGC 7769 you will find a 12.3-magnitude companion designated **NGC 7771**. This SBa-type spiral is almost as bright as NGC 7769 and measures 2.7' by 1.3', appearing somewhat extended northwest-southeast. In 6-inch scopes the core is brighter than the surrounding haze but little detail is visible. In 12-inch telescopes the core is slightly brighter and extended. **NGC 7770** is the last member of the trio. Situated south of NGC 7771, this 14.5-magnitude Sa-type spiral measures 1.0' by 0.9' and appears as a faint circular patch of light in a 12-inch scope at high power.

If you travel across the Square of Pegasus to its southwestern corner, you'll come upon Alpha Pegasi, the brightest star in Pegasus. Northwest of Alpha lie several faint galaxies. About a degree northwest of Alpha Pegasi you'll spot the Sc-type spiral **NGC 7448**. This 11.7-magnitude object is elongated southeast-northwest and measures 2.7' by 1.3'. In 6-inch and



NGC 1, NGC 2, and NGC 16
Mags. 13.4_p, 14.8_p, and 12.0 Sizes 1.9' by 1.5', 1.4' by 0.9', and 2.1' by 1.2' by Bill Sorrells



NGC 7814
Mag. 10.5 Size 6.3' by 3.2' by Bill Iburg

8-inch telescopes NGC 7448 is faint with no central brightening. With a 12-inch scope, the galaxy's oval shape is a bit more distinct and the core appears bright and somewhat mottled.

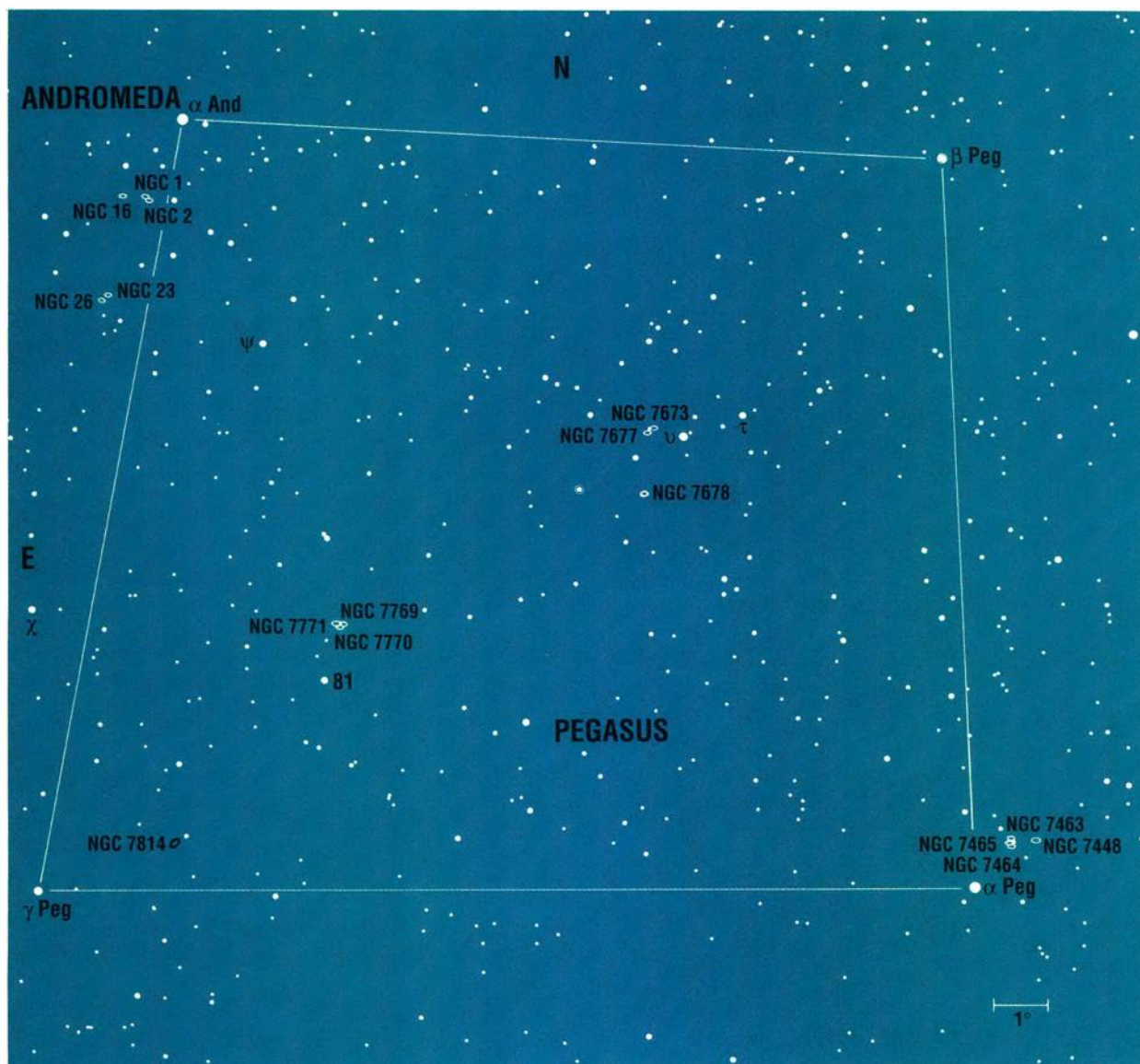
Some 30" east of NGC 7448 lies a fascinating group of galaxies. **NGC 7463**, **NGC 7464**, and **NGC 7465** are all faint in small telescopes but do provide an interesting challenge for users of small scopes. NGC 7465 is the brightest of the three, glowing at magnitude 13.3 and measuring 1.6' by 1.0'. This type SB0 barred spiral is oval in shape with no apparent nuclear brightening visible in small scopes. In 12-inch scopes the nucleus becomes brighter with a uniform haze surrounding it.

NGC 7464 is the faintest of the three and lies just to the west of NGC 7465. At magnitude 14.3, NGC 7464 appears very faint in 6-inch or 8-inch scopes. Measuring 0.7' across, this faint elliptical galaxy presents a faint round haze that is best seen with averted vision. Even in large backyard scopes there is no central brightening. NGC 7463 is just north of NGC 7464 and, although it is listed at magnitude 13.3, it is not as bright as NGC 7465. (I suspect one of the magnitudes is incorrect.) This faint Sbp galaxy is elongated

east-west and measures 3.0' by 0.8'. In small scopes it does not show any central brightening and even larger scopes don't show much more than a uniform haze.

Beta (β) Pegasi marks the northwestern corner of the Great Square and serves as the starting point for our last three galaxies. About 6° southeast of Beta you will find the 4th-magnitude star Upsilon (υ) Pegasi. Aim your scope 30' east of Upsilon and you'll see a pair of contrasting galaxies that will challenge your perception skills. **NGC 7673** is the brighter and larger of the two. At magnitude 12.7, this type Sc peculiar spiral measures 1.7' by 1.6' and is elongated north-south. Telescopes in the 6-inch to 8-inch range show NGC 7673 as a small oval haze with very little central brightening. The challenging galaxy **NGC 7677** lies just a few arcminutes southeast of NGC 7673. Glowing at magnitude 13.9 and measuring 1.9' by 1.2', this galaxy has a very low surface brightness. Averted vision reveals a faint, slightly elongated haze with a small central condensation.

Move your telescope a little over 1° southeast of Upsilon and you'll see **NGC 7678**, an Sc-type galaxy that radiates dimly at magnitude 12.2 and measures



Galaxies in the Great Square

Object	R.A.(2000.0)Dec.	Mag.	Size
NGC 7814	0h03.3m +16°09'	10.5	6.3' by 3.2'
NGC 1	0h07.3m +27°43'	13.4 _p	1.9' by 1.5'
NGC 2	0h07.3m +27°41'	14.8 _p	1.4' by 0.9'
NGC 16	0h09.1m +27°44'	12.0	2.1' by 1.2'
NGC 23	0h09.9m +25°55'	12.0	2.0' by 1.9'
NGC 26	0h10.4m +25°50'	13.9 _p	2.2' by 1.6'
NGC 7448	23h00.1m +15°59'	11.7	2.7' by 1.3'
NGC 7463	23h01.9m +15°59'	13.3 _B	3.0' by 0.8'
NGC 7464	23h01.9m +15°58'	14.3 _B	0.7' by 0.7'
NGC 7465	23h02.0m +15°58'	13.3 _B	1.6' by 1.0'
NGC 7673	23h27.7m +23°35'	12.7	1.7' by 1.6'
NGC 7677	23h28.1m +23°32'	13.9 _p	1.9' by 1.2'
NGC 7678	23h28.5m +22°25'	12.2	2.3' by 1.8'
NGC 7769	23h51.1m +20°09'	12.1	1.8' by 1.8'
NGC 7770	23h51.4m +20°06'	14.5 _p	1.0' by 0.9'
NGC 7771	23h51.4m +20°07'	12.3	2.7' by 1.3'

Object: Designation in NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude; subscript P denotes photographic magnitude and subscript B denotes blue magnitude. **Size:** Diameter in arcminutes.

2.3' by 1.8'. NGC 7678 lies in a triangle of 11th-magnitude stars. Once you spot the little triangle, a keen look with averted vision will reveal the soft light of the galaxy. In 6-inch to 8-inch scopes NGC 7678 is an even glow with no central brightening. In 12-inch scopes the nucleus appears somewhat brighter than the surrounding nebulosity. In large backyard telescopes, those 16 inches and larger, NGC 7678 is slightly elliptical and its nucleus is much brighter than the haze surrounding it.

Autumn evenings provide a cool, comfortable time for galaxy hunting. During these convenient nights Pegasus and its Great Square ride high along the meridian and offer a unique and curious blend of galaxies both large and small, bright and challenging. Try finding a few of these remote denizens of the cosmos and you'll be exploring a region of space millions of light-years from home. □

David Higgins is the central coordinator of the National Deep Sky Observers Society and a contributing editor of Deep Sky magazine.

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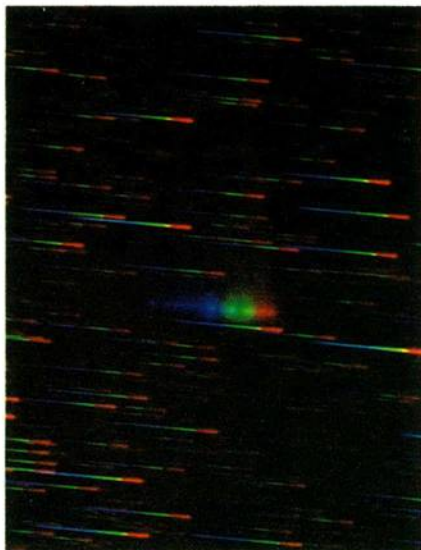
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CONSISTENTLY (SORT-OF) BRIGHT COMETS



AUSTIN'S SPECTRUM was captured using a 400mm f/6.3 lens, Ektar 100 film, and a 15-minute exposure. To spread out the comet's colors, Chris Schur used a 15° objective prism.

By the summer of 1990 amateur astronomers had grown accustomed to viewing reasonably impressive comets. After a spate of decidedly unimpressive entries in the late 1980s, several recent comets have been, well, *almost* bright. The current crop of comets has hung at least one good comet in the sky at all times. It all started with the periodic Comet Brorsen-Metcalf (1989o), which reached 5th magnitude in September 1989. Next, Comet Okazaki-Levy-Rudenko (1989r) reached 6th magnitude in November 1989. Comet Aarseth-Brewington (1989a₁) peaked at 3rd magnitude in December 1989. Then there was Comet Austin (1989c₁), which topped out at 5th magnitude in April 1990. By early June Comet Levy (1990c) had reached 8th magnitude and promised to brighten to 4th magnitude before fading away.

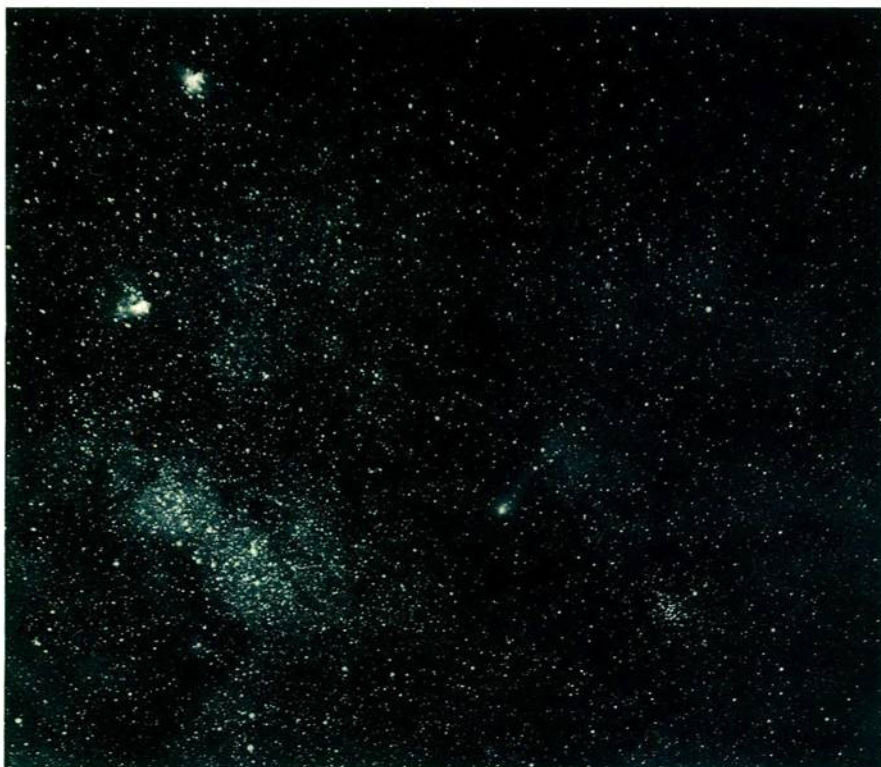
None of these comets has become a spectacular naked-eye comet like 1975's Comet West or 1965's Comet Ikeya-Seki. But the current crop of comets has delivered the goods to those

willing to enjoy them. Viewed with binoculars or a telescope, each of the past five "big" comets has shown a subtle coma and a ghostly, wispy tail.

Marilyn Berry of Tulsa, Oklahoma, is one of the observers who has followed the recent spate of comets closely. "I first became charged with comet fever in 1976 when I saw Comet West," says Berry. "I remember getting up at 4 a.m. and simply going outside to see this giant tail hanging up in the sky — it was breathtaking! With high expectations in mind, I eagerly anticipated Comet Austin when ASTRONOMY began covering it earlier this year.

"After a few weeks, I thought somebody in a high place didn't like me. First it rained for what seemed like weeks. I remained calm. After all, it can't rain forever, I thought. Finally the sky was clear. I got up at 4:30 a.m. and drove across town, got my binoculars out, began scanning, and was blinded by what turned out to be a policeman's searchlight. That was the end of that night. Several days later, I awoke at 3:00 a.m. and went outside. The sky was clear, but it was too early. I went back to sleep. When I awoke over an hour later, the sky was completely overcast.

"I finally did see Comet Austin," says Berry. "I went to a star party of the Tulsa Astronomy Club and got to see the comet through a big scope. It was a small, diffuse patch of light, exciting for what it was and well worth the searching and waiting. I'm now waiting for the next bright comet." — *David Eicher* □



COMET AUSTIN passed through the rich Sagittarius Milky Way in June, sweeping by the Lagoon, Trifid, Eagle, and Omega Nebulae, and the star cluster M23. Photo by Chris Schur.



COMET LEVY brightened slowly during early summer 1990. Jeffrey Jones' photo approximates the view in a small telescope.



DUST ON THE SKY

"Deep black coal dust etched on the sky" — so astronomers of the nineteenth century characterized dark nebulae. These mysterious pockets of black are now known to be clouds of tiny dust particles suspended in front of bright objects that illuminate them. One of the most spectacular examples of a dark nebula is Barnard 72 in Ophiuchus, called the S Nebula or the Snake Nebula because of its distinctive shape. Michael Stecker's outstanding photo of B72 nets this month's \$100 "Best Astrophoto" award (opposite page). Stecker used an 8-inch f/4 Takahashi scope, hypered Tech Pan film, and a 30-minute exposure.

On January 29, 1990, Jim Egger caught an unusual pair of sky objects, namely Jupiter and the big bright star cluster M35 in Gemini (below). Jupiter's slow motion past the cluster provided astrophotographers many opportunities to record objects near and far on one film frame. Steve and Sue Rismiller were determined to include a foreground object in their photo of Omega Centauri made during the 1990 Texas Star Party. Accordingly, they captured Omega Centauri posed above the dark dome of the 107-inch telescope at McDonald Observatory (below left).

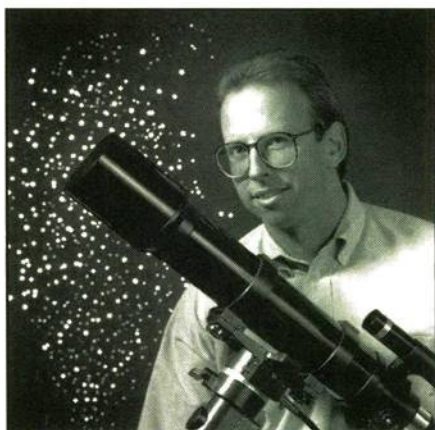
The solar system offered plenty of attractions early this summer, too. Lauri Mala photographed Cassiopeia enveloped by aurorae from Paavola, Finland, on February 25, 1990 (left). Norman Butler used his 8-inch SCT and a Panasonic CCD 200 camera to record lunar craters Ptolemaeus, Alphonsus, Arzachel, and Albategnius (bottom).





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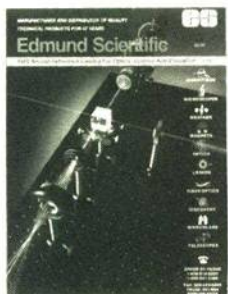
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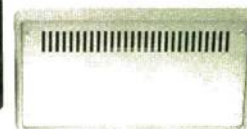
New Astronomy Products



1



2



3



4

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

1 Celestron Ultima Eyepieces

The new Ultima series of eyepieces features multi-coating on each air-to-glass surface. Each model uses computer-designed lenses claimed to minimize spherical aberration, coma, astigmatism, distortion, color, field curvature, and spherical aberration of the exit pupil. All eyepieces feature threaded barrels for filters, blackened insides and lens edges, rubber grips and eyecups, and lens and barrel caps.

Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503; (800) 421-1526 or (213) 328-9560 (8 a.m. to 4 p.m. Pacific Time). Prices start at \$90.00.

2 TeleVue 2x Big Barlow

This giant Barlow allows users to double the power of their favorite long eye-relief 2-inch and 1-1/4-inch eyepieces. The Big Barlow features multi-coated high refractive index glasses claimed to provide optimum aberration correction and high contrast. Also standard are threads for 48mm filters, a captive lock screw, and a parfocal 2-inch to 1-1/4-inch adapter. (The Big Barlow is shown with TeleVue 1.8x and 2.5x 1-1/4-inch Barlows.)

TeleVue Optics, Inc., 20 Dexter Plaza, Pearl River, NY 10965; (914) 735-4044. \$295.

3 Cryocam 80 CCD Camera

The Cryocam 80 is a complete CCD imaging system packaged with Astro-Link controlling and enhancing software for IBM-PC 286- and 386-based computers. The camera is cooled to -80° C, which allows exposures up to several hours. This is achieved without liquid coolants. The CCD is a 572 by 485 pixel array in an area 8.8 mm by 6.6 mm.

Micro Lumimetics, Inc., 3447 Greenfield Avenue, Los Angeles, CA 90034; (213) 838-0690. Systems available for under \$10,000.

4 Vela CCD Imaging System

The new Vela CCD system is offered in two versions. The Model 202 is a complete, stand-alone image acquisition unit. It requires only a telescope adapter and TV monitor. The Model 201 is a partial system with the CCD, thermoelectric cooler, sealed housing, and basic electronics package. Both models use a Philips 610 by 488 pixel chip with an imaging area of 4.5 mm by 6.0 mm.

Western Research Company, Inc., 2127 E. Speedway, Suite 209, Tucson, AZ

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Cat computer ... 995	Sky/dust seal ... 45
Dec 39 ... 99	Set circle illum ... 44
Digital readout ... 389	Star diagonal 2" ... 189
Elec foc 1200A ... 249	Tele extender ... 33
Filter set of 6 ... 84	Tele comp syst ... 63
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Illum EP 419 ... 96	T-adapt-vari ... 49
LED map light ... 29	T-mt.-non AF ... 14
Lenshood 8" ... 59	T-mt.-AF ... 19
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Nebula 1.25" ... 69	Weight set 8" ... 84
Nebula 2" ... 129	Weight set 10" ... 89
Nebula rear-cel ... 109	WFAS ... 114
Off-axis syst ... 169	Partial listing only, please call for others!
Piggy brkt 8" ... 33	

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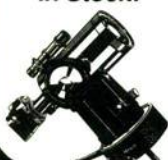


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Barlows	24.5mm 139
122 1-1/4" 2x .. 45	32mm 209
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15mm 129	16mm Type2 .. 279
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DS-16A/B	\$1899 (110.0)
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Field Ed.	\$18.95 (10.0)

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Atlas of Deep Sky Splendors	\$49.95 (10.0)
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Tele Vue



TeleVue Eyepieces Plossl

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55mm	\$219 (3.28)

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Nagler

4.8mm	\$149 (2.87)
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12mm type 2	\$255 (3.53)
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20mm type 2	\$349 (4.10)

Barlow

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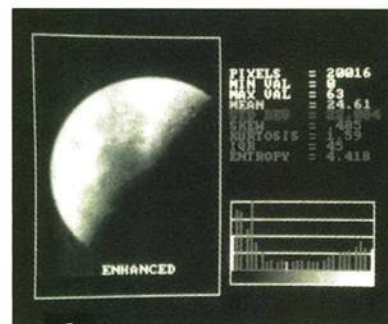
Closeout Special!

Celestron 30 Plossl Eyepiece	\$49 (2.62)
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5



6

85719; (602) 325-4505. Complete Vela CCD System: \$4,500; Camera and basic electronics package: \$2,150.

5

Electrim EDC-1000 (Cooled Version) CCD Camera

Measuring only 2.5 by 2.25 inches, the new version of the EDC-1000 is a thermoelectrically-cooled CCD camera capable of long duration exposures. It comes with a standard C-mount lens flange (for attaching C-mount movie and video lenses and camera-to-telescope adapters) and a plug-in interface card for IBM-PC and compatible computers. The chip is a 192 by 165 pixel array capable of interlace operation which will provide up to 330 pixels of vertical resolution.

Electrim Corporation, P.O. Box 2074, Princeton, NJ 08543; (609) 799-7248. \$760.

6

Image Software for Electrim CCD Camera

This series of image-enhancement software modules is for users of the Electrim line of CCD cameras. The basic black-and-white module has functions for image processing and analysis. An additional module allows color processing. A third module is for converting pictures to and from various image file

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7



8

formats. The software is for IBM-PC and compatibles and requires MCGA/VGA display capability.

TRIFID Corporation, 744 Office Parkway, Suite 224, St. Louis, MO 63141-7128; (314) 991-3095. B&W Module \$295; Color module \$150; File conversion module \$50.

7 Seikosha VP-1500 Video Printer

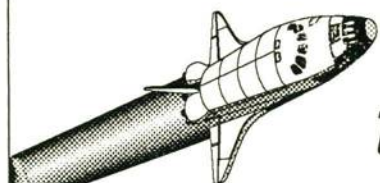
The VP-1500 is a compact thermal video printer that combines 256-step gray scale output with a five-second printout speed. It uses a new high-contrast coated paper and has a maximum print resolution of 1,360 dots by 640 dots. The VP-1500 handles various video inputs including composite video and analog RGB signals.

Seikosha America, Inc., 10 Industrial Avenue, Mahwah, NJ 07430; (201) 327-7227. \$1,995.

8 MOVIT Wireless Robot

OWI Inc. offers a line of computerized, battery-operated robot kits designed to teach the principles of robotic sensing and locomotion. The new CATRAT robot (depicted) features wireless infrared remote control.

OWI Incorporated, 1160 Mahalo Place, Compton, CA 90220; (213) 638-4732. \$59.95. □



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"On the Moon and Jupiter, the Odyssey 8 showed as much detail as several 8" Schmidt-Cassegrains nearby."
David McGough, Millington, N.J.

"It is worth twice what I paid, but please don't raise the price. I want to get my son one in a few years."
Tom Johnston, Boulder, Colo.



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"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
Lee Johnson, Coquitlam, B.C. Canada



13.1 inch \$575.00

"In amateur astronomy for over 35 years and I have seen my share of all kinds of telescopes, good and bad. To say the least, the Odyssey 1 outperforms any thing that I have seen!"
Richard Ziegler, Maumee, Ohio

"There is not another telescope of equal size in our club that can touch the clear image and ease of operation that Odyssey 1 provides."
Mark Davenport, Pinellas Park, Fla.



17.5 inch \$1150.00

"I've only had a chance to view once so far, but am thoroughly thrilled with it. Viewing from a (Santa Barbara, Ca.) residential front yard, the Orion Nebula was indeed a treat - reddish tinges on the predominating green, with many subtle wisps and lanes very clear. The Andromeda Galaxy was surprisingly bright, as was its companion." David Broad, Santa Barbara, Ca.



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Product Reviews

\$1,000 WORTH OF EYEPIECES — PART TWO

14mm Ultra Wide Angle Eyepiece, (Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, CA 92626; (714) 556-2291), list price: \$430.00.

13mm Nagler and 12mm Type 2 Nagler Eyepieces, (TeleVue, 20 Dexter Plaza, Pearl River, NY 10965; (914) 735-4044), list price for 13mm: \$310.00; for 12mm: \$325.00.

Until a few years ago, observers considered fuzzy stars at the edge of the field a fact of life in all wide-angle eyepieces. Indeed, the Meade and TeleVue 40mm models we looked at in Part 1 in the August issue both showed traces of such off-axis aberrations. However, in 1982, Al Nagler and his TeleVue company introduced the revolutionary eyepiece that carries his name. The new design produced nearly pinpoint stars right to the edge of the field, with an apparent field 25 percent wider than in previous wide-angle designs.

In 1986 Meade introduced a line of eyepieces to compete with the Naglers, their Series 4000 "Ultra Wide Angles." This month we'll look at three premium models: the 14mm Meade Ultra Wide, the 13mm TeleVue Nagler, and the 12mm TeleVue Nagler Type 2.

TeleVue advertises an apparent field of 82° for their models, while Meade claims 84°. However, when the eyepieces were held up to the light to compare their apparent fields, the Nagler 13mm showed a field that was slightly wider than the other two. All three have generous fields by any standard.

To check their performance we tested all three eyepieces on two quality refractors known for their wide, flat field: an Astrophysics 4-inch Starfire and a TeleVue 4-inch Genesis. Star images in all three eyepieces were tight and pinpoint in the center. In both telescopes, edge-of-field performance was truly impressive, with no significant difference among the three units with either telescope. Each showed stars flaring from slight astigmatism and lateral color only at the extreme edge of the field.

The 13mm Nagler does have a unique property called "spherical aberration of the exit pupil." This creates dark, kidney-bean-shaped shadows around the field if your eye is not centered. (See TM #20, p. 50 for details.) This idiosyncrasy bothers some observers, but in practice at night with your eyes fully dark adapted the shadows aren't that noticeable. However, the

Type 2 Naglers, like the 12mm, have been designed to eliminate this problem. We found the Nagler 12, as well as the 14mm Meade, to be free of obvious kidney-bean shadows.

Another plus for the Meade and the Nagler 13 was their long eye relief — your eye does not have to be close to the lens to see the entire field. We measured the Meade's eye relief as a generous 18 mm. For the Nagler 13 the eye relief was 14 mm. The Nagler 12 had the smallest eye relief, though it was still a comfortable 8 mm. The Nagler 12's rubber eyecup also helped make it a very pleasant eyepiece to look through. The 13mm we tested was an older unit and did not have a rubber eyecup. However, all the Naglers are now supplied with eyecups as standard fittings, as are the other TeleVue eyepieces. It's a feature we like.

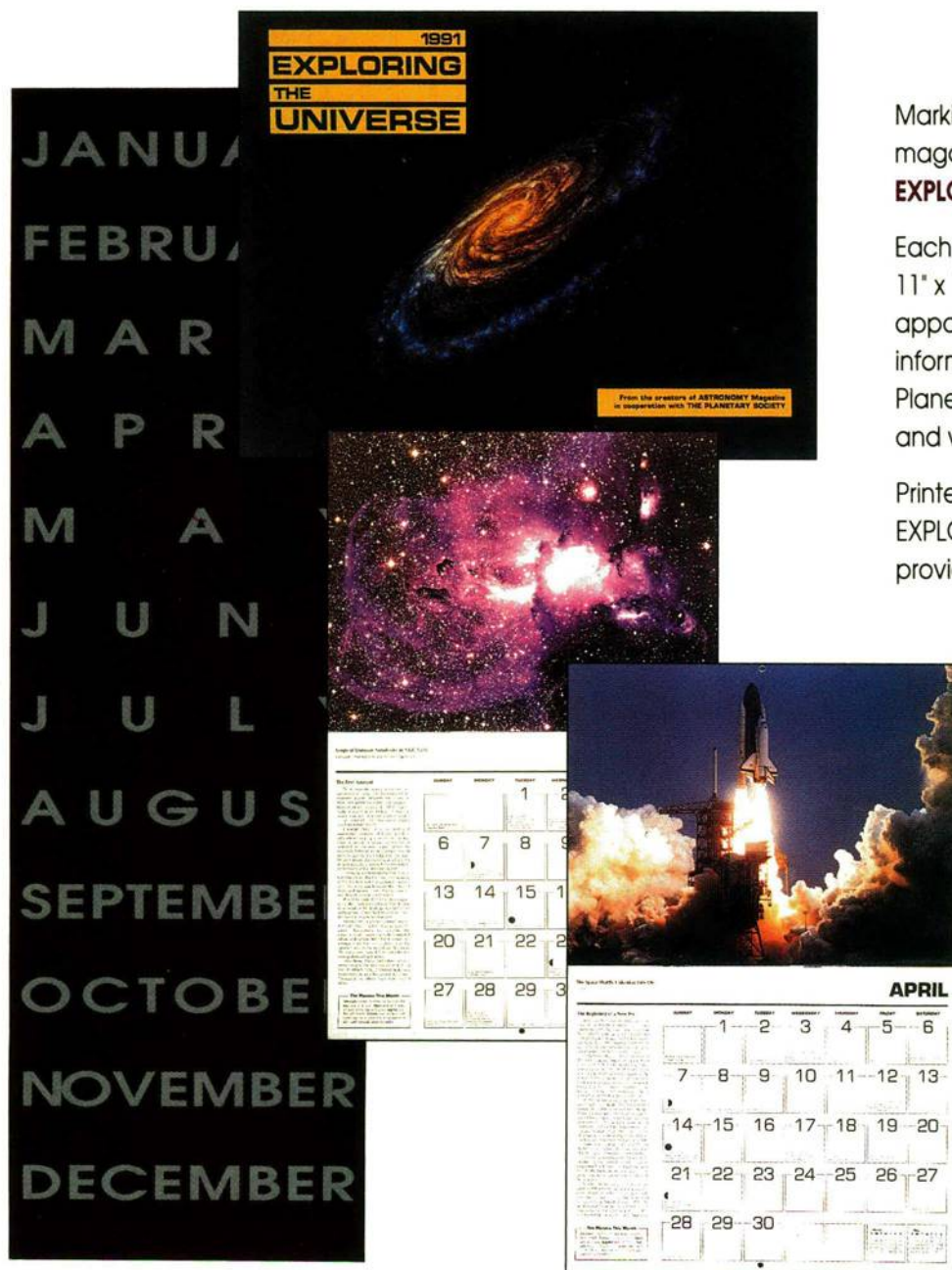
All three have dual-barrel designs that allow them to be used in either 2-inch or 1-1/4-inch focusers. One annoyance with all three eyepieces (and other dual-barrel units) is that the bottoms of their barrels are not blackened. When looking at lunar occultations and earthshine on the Moon, light from the part of the Moon just outside the field hits the barrel and scatters through the field.

When used under more normal circumstances, ghost images are extremely well-suppressed in all three eyepieces, remarkable considering the seven or eight lens elements in each. In each eyepiece a single dim ghost image was visible when looking at an object as bright as Jupiter. The ghost image was brightest in the 14mm Meade and least noticeable in the 13mm Nagler.

The 13mm and 14mm eyepieces each weigh a substantial 1 pound 8 ounces. The 12mm Nagler is the smallest and lightest of the trio, weighing in at 1 pound 1 ounce. The discounted price for each eyepiece at most dealers ranges between \$230 to \$260.

Which of the three is best is impossible to say. Each has its selling points. Yes, they are expensive. But the 13mm and 12mm Naglers and the 14mm Meade Ultra Wide eyepieces, as well as the Meade and TeleVue 40mm wide-angle models we reviewed in August, are superb eyepieces. They all provide a winning combination of wide field and optical quality. But a warning: if you buy one of these premium eyepieces, you'll soon want more. It can become a costly habit! — Alan Dyer □

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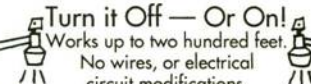
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Astronomy Books

GALACTIC NEBULAE FOR OBSERVERS AND ASTROPHOTOGRAPHERS

Atlas Galaktischer Nebel/Atlas of Galactic Nebulae, by Thorsten Neckel and Hans Vehrenberg, (Treugesell-Verlag, 1985 and 1987), 286 plates in two loose-leaf binders, \$68 and \$82. [Publisher's address: Schillerstraße 17, D-4000 Düsseldorf, West Germany]

Because large telescopes are now available to a wide range of observers — a result of the "light bucket" revolution — finding and observing challenging new deep-sky objects has become a field almost unto itself. If it was considered a challenge several years ago to observe all the objects in the Messier list, today even the faintest NGC object is within the reach of the larger light buckets.

But how is the eager backyard observer going to find his or her way to all these objects? Magazines such as *Deep Sky* and *ASTRONOMY* are a help, but their lists are limited. Comprehensive handbooks exist, but the information in them is often out of date. There is also the professional literature, but this is available only to those observers who live near a university with an active astronomy department.

Neckel and Vehrenberg's *Atlas* was designed to help out the amateur observer by providing an exceptionally large body of reference material. The two binders each contain about 140 individual plates, with several photos per plate. Binder I covers 0h to 12h right ascension, binder II 12h to 24h; both go from the north celestial pole down to -33° declination. Each binder has a 50- to 60-page introductory booklet containing explanations of the atlas (in English and German), listings of objects, and bibliographies.

For the most part, the photos are negative images taken from the Palomar Observatory Sky Survey (POSS). Additional photos come from such sources as the observatories in Spain and Chile of the Max-Planck-Institut für Astronomie and from several amateur astrophotographers including Vehrenberg himself. Each photo has a caption that identifies the nebula, gives its 1950.0 coordinates and the photo scale, and says (where appropriate) whether a red or blue POSS plate was used.

Using the *Atlas* at the telescope is made easier by the loose-leaf publication format. While the pages are not waterproofed, they are printed on heavy stock. Thus as long as you don't

let them get soaked by dew, they will hold up quite well.

Given a price for both parts of \$150, any backyard astronomer has to ask whether this publication is worth the cost. The answer will depend on your level of observing interests. If you are keen to push your telescope and observing techniques to the utmost, then galactic nebulae are an enjoyable and well-populated class of object to search out. This atlas will then be a necessary addition to your observing library.

Its greatest benefit, however, may not lie in helping you find these nebulae. After all, charts such as those in the *Uranometria* make locating even faint, obscure nebulae easy. Instead, Neckel and Vehrenberg's *Atlas* shows its worth when you come to observe a nebula you've never seen before. Thanks to the good deep photos in the atlas, you'll see more at the telescope because you will know what the object looks like. (Some of these nebulae, however, may be too faint to be seen even in a large telescope.) Avid astrophotographers, on the other hand, will find here a grand collection of photos to browse through, and an excellent rogues' gallery of nebulae to try their skills on. — David Higgins

The Moon and Solar System

Proceedings of the Twentieth Lunar and Planetary Science Conference, edited by Virgil Sharpton and Graham Ryder, (Lunar and Planetary Institute, 1990), ISBN 0-942862-04-X, 591 pages, hardcover, \$50.00.

The Lunar and Planetary Science Conference held each spring at the Johnson Space Center in Houston gives planetary scientists from around the world a chance to present and discuss new findings. This volume publishes the 50 most important papers given at the twentieth annual conference in March 1989. It includes sections on the geology, petrology, and geochemistry of the Moon; comets and meteorites; impact cratering; and the geologies of Mars and Venus.

Stars and Galaxies

Structure and Dynamics of the Interstellar Medium, edited by G. Tenorio-Tagle, M. Moles, and J. Melnick, (Springer-Verlag, 1989), ISBN 0-387-51956-4, 535 pages, hardcover, \$62.70.

This book contains papers given during the International Astronomical Union colloquium on the structure and dynamics of the interstellar medium, held in Granada, Spain, April 1989. Pa-

pers address such topics as molecular clouds and star-forming regions, mechanical energy sources, disks, outflows, jets, Herbig-Haro objects, the Orion Nebula, and the extragalactic interstellar medium.

General Astronomy

Visions of Space, by David Hardy, (Paper Tiger Press, 1989), ISBN 1-85028-098-3, 176 pages, hardcover, \$39.95.

This large-format (about 10 by 12 inches) all-color book is a glorious feast of imaginary scenes set on other worlds. The book begins with a look back at the work of Chesley Bonestell, the artist who created space art almost single-handedly in the 1940s and 1950s. It continues by lavishly showcasing the work of about seventy artists working today. Space stations, the moons of Neptune, Ionian volcanos, Martian sandstorms and settlements — if you enjoy exploring "Man's dreams of worlds unseen," this is where you'll find them.

BRIEFLY NOTED

Stars

Evolution of Peculiar Red Giant Stars, edited by Hollis R. Johnson and Ben Zuckerman, (Cambridge University Press, 1989), ISBN 0-521-36617-8, 440 pages, hardcover, \$54.50.

Multimode Stellar Pulsations, edited by G. Kovacs, L. Szabados, and B. Szeidl, (Kultura, Kulkereskedelmi Vallalat, H-1389 Budapest 62, P.O. Box 149), ISBN 963-8361-29-8, 299 pages, hardcover, no price given.

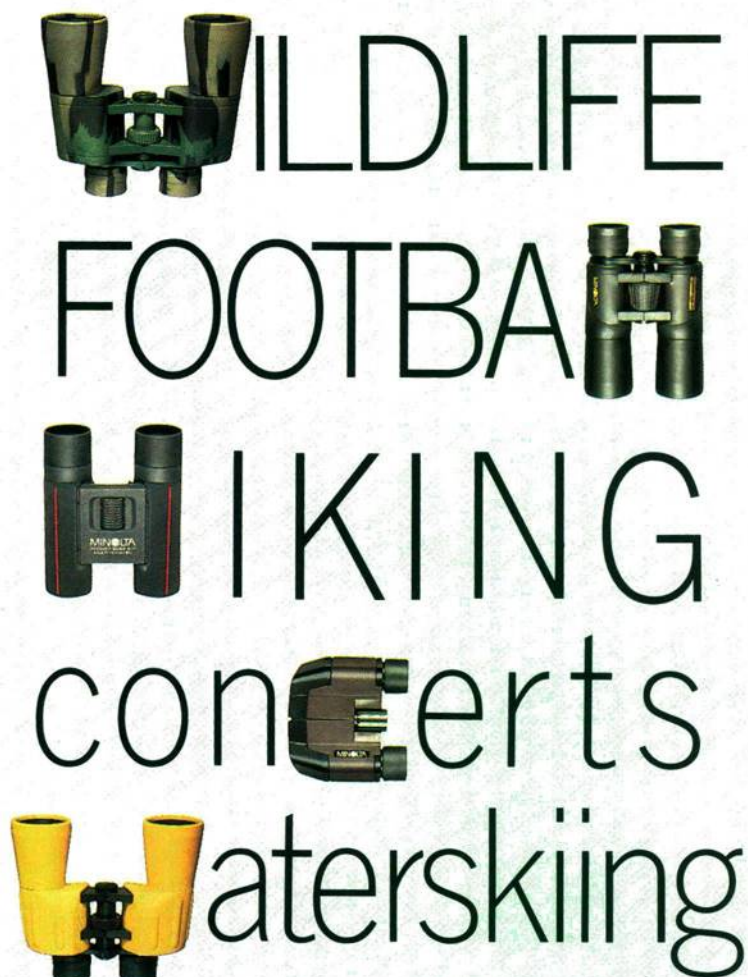
Nonradial Oscillations of Stars, second edition by Wasaburo Unno, Yoji Osaki, Hiroyasu Ando, Hideyuki Saio, and Hiromoto Shibahashi, (Columbia University Press, 1989), ISBN 0-86008-439-6, 420 pages, hardcover, \$64.50.

Polarized Radiation of Circumstellar Origin, edited by G. V. Coyne, A. M. Magelhaes, A. F. J. Moffat, R. E. Schulte-Ladbeck, S. Tapia, and D. T. Wickramasinghe, (University of Arizona Press, 1989), 795 pages, hardcover, \$48.00.

Telescopes and Instruments

Very Long Baseline Interferometry: Techniques and Applications, edited by Marcello Felli and Ralph E. Spencer, (D. Reidel, 1989), ISBN 0-7923-0376-8, 437 pages, hardcover, \$109.00.

X-Ray Detectors in Astronomy, by G. W. Fraser, (Cambridge University Press, 1989), ISBN 0-521-32663-X, 302 pages, hardcover, \$69.50. □



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36th Annual AstroAssembly, Seagrave Memorial Observatory, North Scituate, Rhode Island. Sponsored by Skyscrapers, Inc. Contact: Brian Magaw, P.O. Box 325, Pascoag, RI 02859. Phone: (401) 568-8424.

September 29

Astronomy Day, Pensacola, Florida. Sponsored by the Escambia Amateur Astronomers Association. Contact: Margret Hildreth, 4100 Lillian Highway, Pensacola, FL 32506. Phone: (904) 456-0078.

October 10-13

26th Annual Conference of the Great Lakes Planetarium Association, Children's Museum of Indianapolis, Indiana. Contact: Sharon K. Parker, SpaceQuest Planetarium, The Children's Museum of Indianapolis, 3000 North Meridian Street, Indianapolis, IN 46208. Phone: (317) 924-5431.

October 12-14

Georgia Star Party, Hard Labor Creek State Park, near Atlanta, Georgia. Sponsored by the Astronomical Society of the Atlantic. Contact: Astronomical Society of the Atlantic, c/o Center for High Angular Resolution Astronomy, Georgia State University, Atlanta, Georgia 30303. Phone: (404) 264-0451.

October 12-14

13th National Astronomy Encounter of the Venezuelan Amateur Astronomers, Guayana, Venezuela. Sponsored by Venezuelan Astronomical League. Contact: D. Sánchez, Sociedad de Astronomía, Apartado 368, Ciudad Guayana 8015, Estado Bolívar, Venezuela.

October 18-21

8th Annual Deep South Regional Star Gaze, Percy Quin State Park, McComb, Mississippi. Contact: Mark Stauffer. Phone: (504) 359-2156 (days), (504) 273-2320 (evenings).

October 19-20

8th Annual Northern Virginia Telescope Meet, C. M. Crockett Park, Calverton, Virginia. Contact: Al Schumann, 6121 Rivanna Drive, Springfield, VA 22150. Phone: (703) 256-4777.

October 19-20

Twin Lakes Star Party. Sponsored by the West Kentucky Amateur Astronomers. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211-9001. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

October 19-21

Astronomy Workshop '90, Camp Maskepetoon, south of Edmonton, Alberta. Sponsored by the Royal Astronomical Society of Canada, Edmonton Centre. Contact: George Moores, 2415 107 Street, Edmonton, Alberta T6J 5N4. Phone: (403) 436-2855 (after 6 p.m.).

October 19-21

5th Midwest Space Development Conference, Westlake, Ohio. Contact: Midwest Space Development Conference '90, 524 West 6th Street, Lakeside, OH 43440.

October 19-21

Stella-Della-Valley IV, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association and the Mid-East Region of the Astronomical League. Contact: Greg Mauro, 4 Crosswicks Court, Trenton, NJ 08610. Phone: (609) 585-9465.

October 20

6th Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, near Blowing Rock, North Carolina. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630. Phone: (704) 396-7656.

October 25-27

Great Plains Planetarium Association Annual Meeting, Kansas Cosmosphere and Space Center, Hutchinson, Kansas. Contact: Roger Hoefer, Planetarium Director, 1100 North Plum, Hutchinson, KS 67501.

October 27-28

17th Annual Astronomical Association of Northern California Conference, Lawrence Hall of Science, Berkeley, California. Contact: Don Stone, AANC, 731 Camino Ricardo, Moraga, CA 94556. Phone: (415) 376-3007.

November 2-3

Stargazing Weekend, Pennyriple Forest State Resort Park, Dawson Springs, Kentucky. Contact: Dean Henson, Park Naturalist, 20781 Pennyriple Lodge Road, Dawson Springs, KY 42408. Phone: (800) 325-1711. □

Please submit announcements at least four months before the date of the meeting or event.

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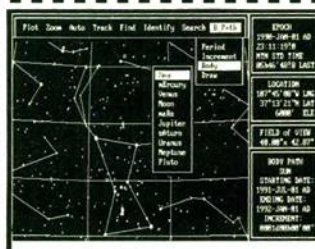
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Readings and Resources

The Largest Stars (page 30)

Cycles of Fire by William K. Hartmann, (Workman Publishing Co., 1987). One of the best popular works on the life cycles of stars and the many varieties of stars in the Galaxy. Illustrated with many space art paintings.

The Stars: From Superstition to Supernova by Heather Couper and Nigel Henbest, (Pan Books, 1988). Produced to complement a popular British television series, this book is a well-illustrated review of what astronomers know about stars and how they study them. The book was written by two of Britain's leading science writers.

Uranus and Neptune (page 42)

The best sources for an overview are

the issues of the periodical *Science* that contain the preliminary science reports from the *Voyager* investigation teams. The Uranus issue is July 4, 1986; Neptune's is December 15, 1989. (Try a large public or university library.)

Atlas of Uranus by Garry Hunt and Patrick Moore, (Cambridge University Press, 1989). A straightforward popular account of the planet compiled by a noted planetary scientist and a well-known amateur observer.

Uranus and Neptune by Eric Burgess (Columbia University Press, 1988). A detailed popular account of the 1986 Uranus flyby and a portrait of the planet. (The short Neptune section, however, dates from before the 1989 encounter.)

CREDITS

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COMING IN THE NOVEMBER 1990 ISSUE OF ASTRONOMY

AVAILABLE ON
YOUR NEWSSTAND
OCTOBER 9

THE FUTURE OF GROUND-BASED ASTRONOMY
With many new optical telescopes coming on line, the 1990s promise to be an active and exciting decade for ground-based astronomers.

TELESCOPES FOR ASTROPHOTOGRAPHY
ASTRONOMY helps you select the best telescopes for solar system and deep-sky photography.

MARS AT ITS BEST During November, owners of small telescopes will get their sharpest views of Mars until the twenty-first century.

1990 SWEEPSTAKES WINNERS!

Here are the names of the lucky winners of our 1990 ASTRONOMY sweepstakes. We congratulate them on winning and their prize choices!

Mark Bruskin of Mission Viejo, California, won our \$3,000 Grand Prize Shopping Spree and purchased the following from Lumicon: a Meade 2080 Premier 50 Series telescope with tripod, an NGC Sky Vector, a UHC filter and Deep Sky filter, a TeleVue Type 2 eyepiece, a dew shield, and an accessory case. Mark was also able to choose half a dozen of our colorful space mission patches.

The First Prize in our December drawing, a \$500 Shopping Spree, went to Albert Dukes of Winnsboro, South Carolina. Albert chose a Parks 15x80mm Deluxe Giant Deep Sky Binocular from Scope City, and an Orion Standard Observer's Chair from Orion Telescope Center, and he renewed his subscription to ASTRONOMY.

Mike Kelly of Dubuque, Iowa, won January's \$500 First Prize Shopping Spree and selected a Sky Explorer 60mm Equatorial Refractor and an 8x56mm Sky Explorer Mini Deep Sky Binoculars from Orion Telescope Center. He also chose three astronomy books from Kalmbach Publishing for his library.

February's \$500 First Prize Shopping Spree was awarded to Dale Flamand of Sterling Heights, Michigan. Dale shopped for a Vogel Digitrak II quartz drive corrector and a Thousand Oaks solar filter from Wholesale Optics of Pennsylvania. He also selected one of P. J. LaCock's "Star" Dust covers for his telescope; a dew removal gun and deluxe metal-clad accessory case from Orion Telescope Center; a Jim's Mobile Industries' Motofocus from Focus Camera, Inc.; and a poster from Kalmbach.

Six ASTRONOMY readers won complete sets of astronomy books from Kalmbach, and nine readers won five-year subscriptions to ASTRONOMY.

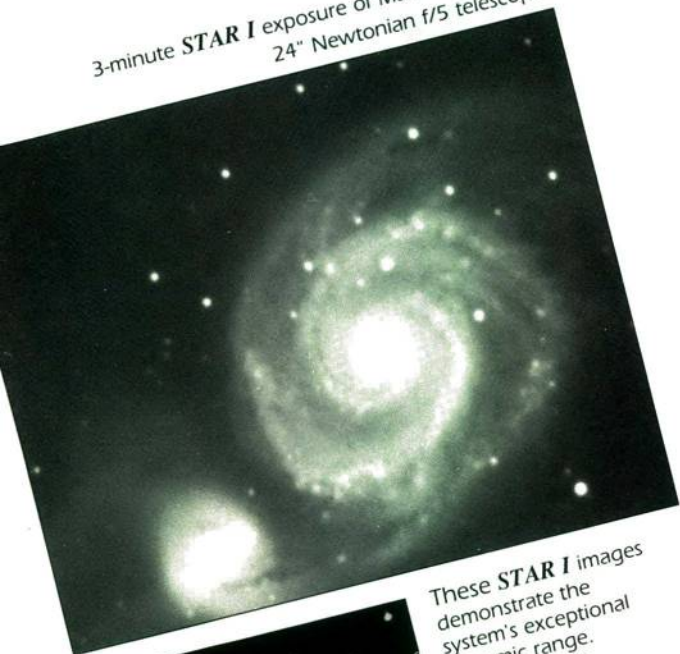
We have another sweepstakes coming up in the November, December, and January issues of ASTRONOMY. Watch for it — enter — and you, too, may be a winner!

NEW!

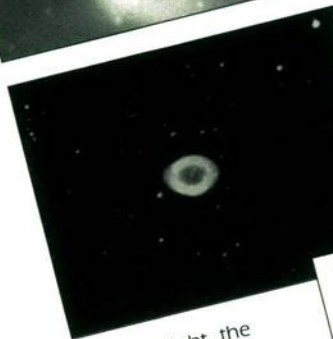
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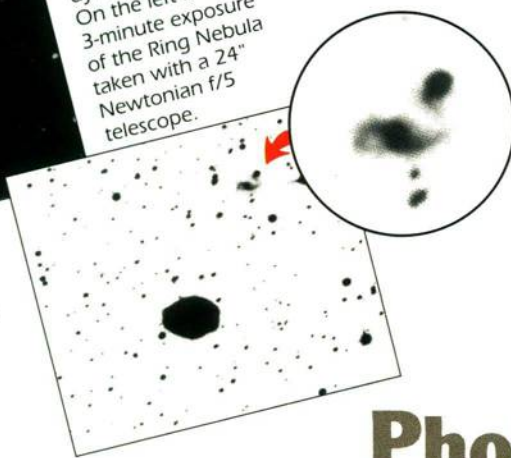
3-minute **STAR I** exposure of M51 taken with a
24" Newtonian f/5 telescope.



These **STAR I** images
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On the left is a
3-minute exposure
of the Ring Nebula
taken with a 24"
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telescope.



On the right, the
same image is
inverted and
rescaled to highlight
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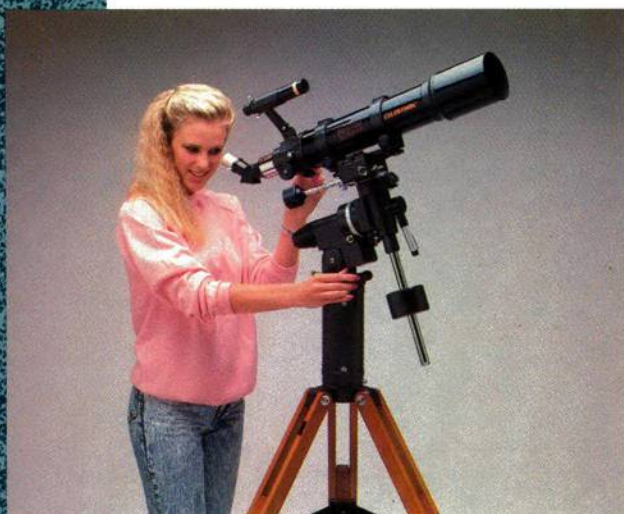

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REFRACTORS FROM CELESTRON



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Firstscope 80



SP-C102F

Best known for manufacturing premium quality catadioptric telescopes, Celestron also features a complete line of refractors for serious users. Refractors that compare favorably with the best the industry has to offer. In fact, the **SP-C102F was ranked the top performer when compared against competitive units in Astronomy Magazine's June 1990 review.**

All of our standard refracting telescopes are fully coated, diffraction limited and utilize high quality optical glass for the achromatic objective lenses. The achromatic objectives of the 80mm and 102mm are air spaced to give a higher optical quality than the competition. The premium quality SP-C102F uses multicoated lenses and has a fluorite element which gives the best color correction, resolution and contrast of any refractor.

Celestron's 80mm and 102mm refractors feature:

- metal tube
- attractive adjustable wood tripod with accessory tray
- slow-motion controls in both axes
- 6x30 finderscope
- star diagonal—1¼"
- 18mm Orthoscopic eyepiece—1¼" (80mm)
- 26mm Plössl eyepiece—1¼" (102mm)
- dew shield, lens caps

The Super Polaris equatorial mount is featured on the SP-C80, SP-C102 and SP-C102F models. This deluxe, technically advanced, very sturdy German equatorial mount utilizes precision 144 tooth lapped worm gears in both axes. Fine adjustment controls and setting circles are also provided in both axes. An adjustable counterweight makes it easy to point, balance and use. For easy set-up and operation, a built-in illuminated polar alignment scope is standard (optional on the SP-C80) as is a latitude scale and bubble level. The tripod has excellent vibration dampening characteristics which make observing and photography simple.

For Super Polaris Mounts: Optional state-of-the-art stepping motor drive correctors are available (good for observing and a must for astrophotography!) Another optional accessory, the Advanced Astro Master™ Digital Setting Circles allows you to find objects with ease. The Advanced Astro Master™ is easy to install and features large LED read-outs. This is a real-time readout of RA and DEC coordinates and in addition, has over 8,000 objects in its memory—now improved to include not only the entire RNGC and Messier catalogs but major planets as well.

Great for gifts or those on a limited budget, Celestron also offers 60mm aperture, metal tube refractors in both altazimuth and equatorial versions.



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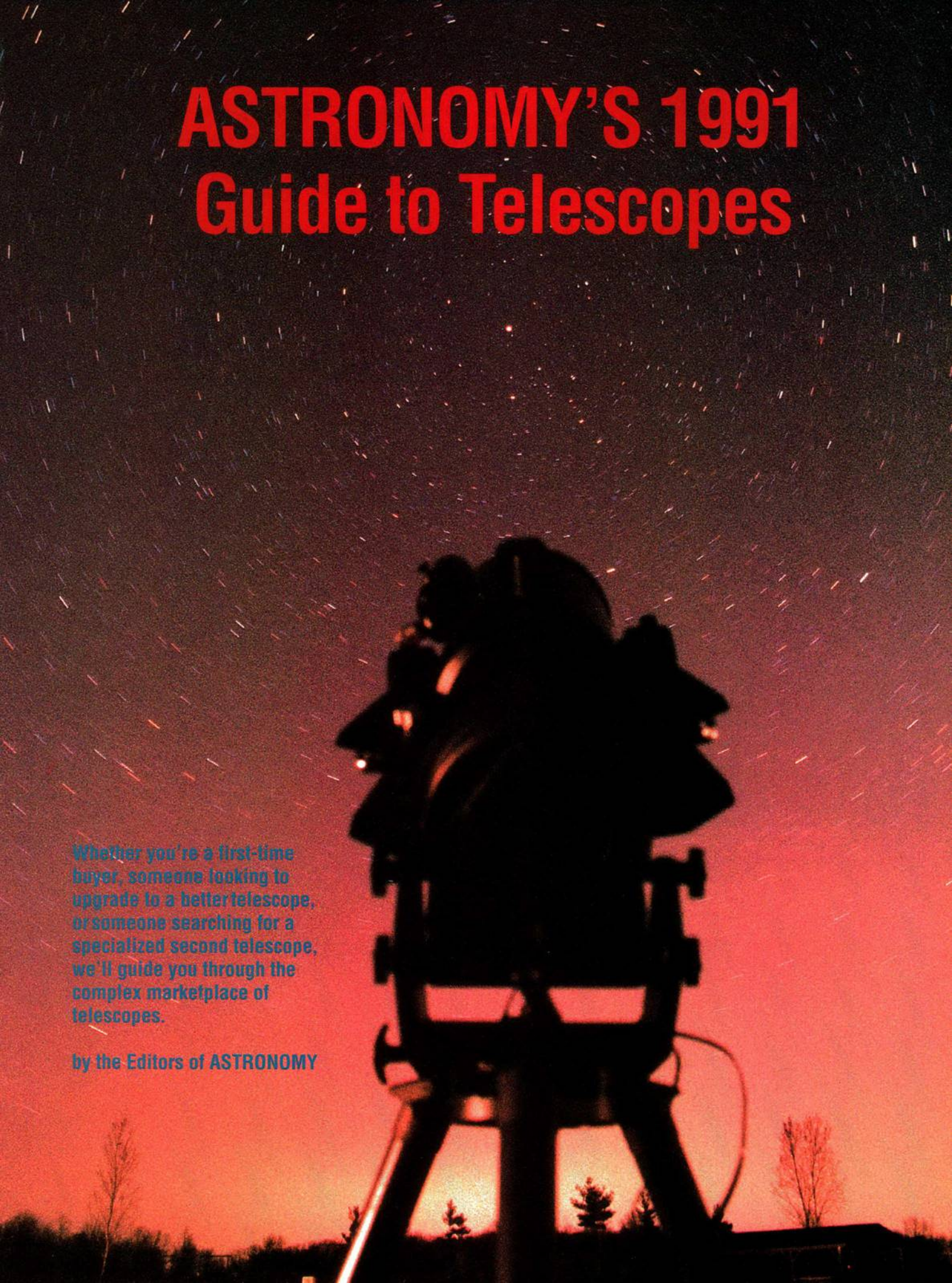
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	FIRSTSCOPE 80	SP-C80	SP-C102	SP-C102F
APERTURE	3.1"	3.1"	4.0"	4.0"
FOCAL LENGTH	910mm	910mm	1000mm	900mm
FOCAL RATIO-f/#	11.4	11.4	9.8	8.8

ASTRONOMY'S 1991 Guide to Telescopes

Whether you're a first-time buyer, someone looking to upgrade to a better telescope, or someone searching for a specialized second telescope, we'll guide you through the complex marketplace of telescopes.

by the Editors of ASTRONOMY



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ASTRONOMY'S 1991 GUIDE TO TELESCOPES

People are often surprised to find so many telescopes on the market. Selecting the right one requires more than simply finding the telescope with the best specifications.

CONTENTS

- C Finding the Best Telescope
- D Performance Specs
- E Telescopes Types
- F Telescopes Terminology
- G The Pros and Cons
- H The Good, the Bad, and the Unnecessary
- J 1991 Telescope Market Survey
- O Telescope Dealer Listings

A telescope is your window on the universe. It can be a source of wonderful entertainment, a focal point for family activities, an educational tool, and the centerpiece of a hobby that can last a lifetime. Compared to other recreational products, a telescope is a good investment. And relatively inexpensive. You can spend thousands of dollars on RVs, boats, snowmobiles, sporting goods, computers, or video equipment, yet \$500 to \$1,000 will get you a quality telescope that will never wear out. And if you should decide to sell your telescope, you can expect to recoup about 70 to 80 percent of your initial cash outlay, even after five or ten years. In return for the money you don't get back, the telescope will have provided you with many hours of pleasure watching the finest show nature has to offer — the night sky. What more could you ask for?

The Telescopic Universe

How much enjoyment you get from your telescope depends on whether it satisfies your expectations. All the telescopes available on today's market are powerful instruments capable of showing you details on the Moon and planets, distant nebulae and star clusters, and galaxies millions of light-years away. But recreational telescopes can't compete with *Voyager* spacecraft or giant observatory instruments on mountain tops. So please keep in mind these caveats:

- Even at high magnification, planets will always be small disks, requiring a patient and trained eye to pick out the often subtle surface details.
- Nebulae and galaxies will always appear in black-and-white. The stunning colors you see in photographs of deep-space objects, even those taken by amateur astronomers, emerge only in long time-exposures.
- No telescope can magnify a star enough to show its true disk. Stars are simply too far away and appear as points of light even through the largest telescopes on Earth.

Forget Power — Think Aperture

Telescopes are rated by aperture. The larger the lens or mirror, the more light it will gather and focus into the final image. Larger telescopes give brighter images. Brighter is usually better. Magnification alone is not important. *Any* telescope can be made to magnify at *any* power, making it meaningless to say a 400x scope is better than a 200x scope. (That's why you should dismiss the advertising claims of "department store" telescopes sold strictly on the basis of magnification.) In fact, in most telescopes any power over 200x is unusable — the images are simply too faint and are blurred by the atmosphere.

Because larger aperture telescopes deliver more light, they're better for looking at faint nebulae and galaxies. In addition, when looking at the Moon and planets, the images in large scopes will withstand high magnifications better. Their images will be brighter and sharper than those in smaller scopes working at the same power, if — and here's the catch — if the optical quality is the same. A smaller telescope with good optics can outperform a large telescope with poor optics. The images will be dimmer in the small scope but they will be sharper, with more contrast. Stars will look like pinpoints not fuzzballs, and lunar and planetary detail will snap into focus. For the best images, light-gathering power should go hand-in-hand with finely made optics. But keeping the two married together can become very expensive as you get into larger telescopes. Costs for top-quality optics can skyrocket exponentially with increasing aperture. So, the best telescope for you will likely be a balanced compromise of aperture, optical quality, portability, and price.



Simulated view through
4-inch scope



Simulated view through
8-inch scope.

PLANETS USUALLY LOOK SHARPER in large aperture telescopes. Photos by Scott Rosen (left) and Jean Dragesco (right).



Simulated view through
4-inch scope



Simulated view through
8-inch scope

DEEP-SKY OBJECTS LOOK BRIGHTER in large aperture telescopes. Photos by David Healy (left) and Scott Rosen (right).

The Best Telescope

"What's the best telescope to buy?" We wish we could give a simple answer. The fact is the telescope market has now become very complicated, with a bewildering variety of models and brands competing for our attention. It's part of a trend: Where once there was one type of cola, there are now half a dozen. Where once there were two or three simple sneakers in the shoe store, there are now entire walls filled with them. So it is with recreational telescopes. You can now pick from many great models, but the variety has made it more difficult to find the right telescope.

First-time buyers often expect to locate *the* single best telescope, period. Unfortunately, such a telescope doesn't exist. Some telescopes are better suited for viewing certain kinds of celestial objects: Long focal length telescopes are usually considered better for planetary observing while short focal length fast *f*/ratio scopes appeal to deep-sky observers. In fact, many amateurs end up owning two or three telescopes with widely different characteristics. Nevertheless, you'll hear lots of advice about what constitutes the single best choice for a telescope. "Get the biggest telescope you can afford" is a common dictum. But we feel that the soundest advice is this: *The best telescope for you is the one you will use most often.* Great optics, wonderful designs, lots of features, and prestigious brand names mean nothing if the telescope sits unused.

Personal Factors

Price would seem to be the most important factor in narrowing your choice, but it's only one of many. To choose a telescope that you'll have fun using you should first ask yourself some questions about your lifestyle:

Where Do You Live?

- Do you live in an apartment? Must you cart your telescope a long way just to take it outside? Once outside do you need to move the telescope around the backyard in order to see different parts of the sky? Does your home have limited storage space? Does your car have a small cargo capacity? If

Performance Specs

Aperture (inches)	(mm)	Faintest Magnitude	Resolution* (arcseconds)	Highest Usable Power*
2.4	60	11.6	2.0	120x
3.1	80	12.2	1.5	160x
4	100	12.7	1.2	200x
6	150	13.6	0.8	300x
8	200	14.2	0.6	400x
10	250	14.7	0.5	500x
12.5	320	15.2	0.4	600x
14	355	15.4	(0.33)	(600x)
17.5	445	15.9	(0.27)	(600x)

*Under most atmospheric conditions, even in large telescopes, magnifications over 500 to 600x and resolutions better than 0.5 to 0.4 seconds of arc are rarely possible.

you answer "yes" to any of these, then you probably shouldn't consider any telescope larger than 4 or 5 inches in aperture.

- Will you be observing primarily from an urban or suburban site with light-polluted skies? Then you shouldn't buy a fast *f*/4 or *f*/5 low-power telescope, especially a "light-bucket" like a large Dobsonian. They are best for dark, rural sites.

- Do you live in a cold climate? Unless the scope is easy to set up and take down, you may never enjoy using it in cold weather.

Who Will Use the Scope?

- Will your telescope be used by other members of the family? By children? If so, you'll again want to keep the telescope rugged and easy to use. A simple altazimuth or Dobsonian-style mount might be fine.

What's Your Personality?

- Do you have a tough time understanding complex hardware? Then avoid German equatorial mounts or anything computerized.

- Do you like convenience and ease of use? Dobsonian-mounted scopes are quick to set up. In an equatorial mount, a basic fork-mounted Schmidt-Cassegrain is one of the most straightforward designs on the market.

- Are you just plain lazy? Come on admit it! If you are, then any telescope over 4 to 5 inches in aperture is likely to be a burden.

- Do you take immense satisfaction in simply owning finely crafted instruments? Then you'll enjoy a telescope like a Takahashi, Questar, or TeleVue Renaissance or Genesis rather than a roughly finished, low-cost Dobsonian.

What About the Long Term?

- Do you think you'll stay with the hobby for a while? Do you want a telescope that will grow with your interests? Then a well-designed expandable system like the Meade Premier Series may be the ticket.

- On the other hand, if there's a chance you or the child you're buying the scope for will lose interest, you'll want a telescope that is inexpensive and easy to sell. A 60mm or 80mm refractor may be the best choice.

Observing Interests

Besides figuring personal circumstances into the equation, you should give some thought to what your observing interests might be.

- Does astrophotography fascinate you? Then an equatorial mount with a clock drive is a must. Look for a telescope with readily available camera adapters, piggyback mounting brackets, guiding accessories, and motor speed controls (a drive corrector). A Schmidt-Cassegrain might be perfect. Or an equatorial Newtonian or an apochromatic refractor system.

Telescope Types

TELESCOPE OPTICS

Refractor: A telescope with a lens at the front of the telescope tube that collects light and focuses it at the bottom of the tube. Combines ruggedness with crisp images. Popular in sizes from 80mm to 5 inches. Principal aberration: Chromatic aberration can add blue or purple haloes around bright objects.

Newtonian Reflector: A telescope in which a concave mirror at the bottom of the tube collects light and reflects it to a small, flat secondary mirror that deflects the light to the eyepiece at the side of the tube. Combines sizable aperture in an economical package. Popular in sizes from 4 inches to 12 inches. Principal aberration: Coma distorts stars off-axis.

Schmidt-Cassegrain Telescope (also called an SCT): A telescope in which a concave mirror collects light and reflects it to a convex secondary mirror which in turn sends the light back down to a focus at the rear of the telescope. A thin corrector plate at the front of the tube compensates for spherical aberration. Combines sizable aperture in a compact tube. Popular in sizes from 4 inches to 8 inches. Principal aberrations: Curvature of field and slight loss of contrast due to large secondary mirror.

TELESCOPE MOUNTS

Any of these optical designs can come on one of several basic types of mounts.

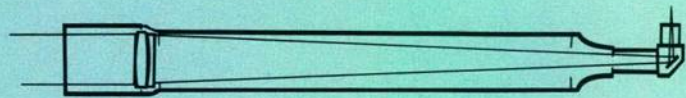
Altazimuth Mount: An inexpensive and easy-to-use mount that swings left-to-right and up-and-down. The best are equipped with smooth, slow-motion controls for making fine position adjustments. Disadvantage: Cannot automatically track the stars.

Dobsonian Mount: Named for its popularizer, telescope-maker John Dobson, this simple, low-cost altazimuth mount is often used on large aperture Newtonians. Disadvantage: Cannot automatically track the stars.

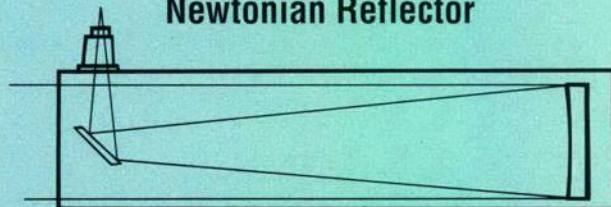
German Equatorial Mount: First used in Germany, this design uses two axes at right angles, with one axis aimed at the celestial pole. This allows the mount to follow the sky with a single motion. Often used with long-tube telescopes like refractors and Newtonians. Disadvantage: Can be complex to set up, has a heavy counterweight, and can be awkward to aim.

Fork Equatorial Mount: A mount in which the tube rests in a U-shaped fork, with the fork tines pointed at the celestial pole. Easy to aim and maneuver. Often used on short-tube telescopes like Schmidt-Newtonians and Schmidt-Cassegrains. Disadvantage: Can be shakier than a German mount and more difficult to balance.

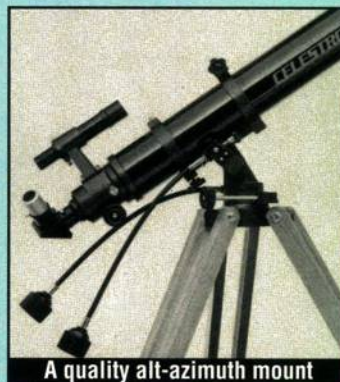
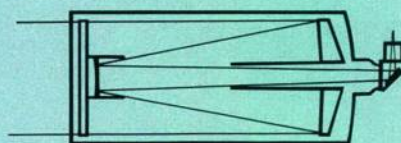
Refractor



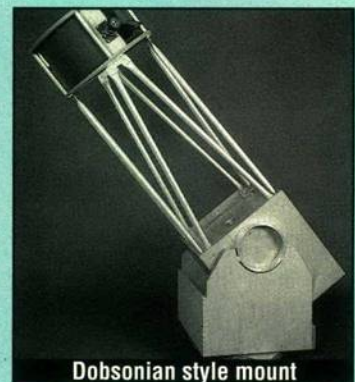
Newtonian Reflector



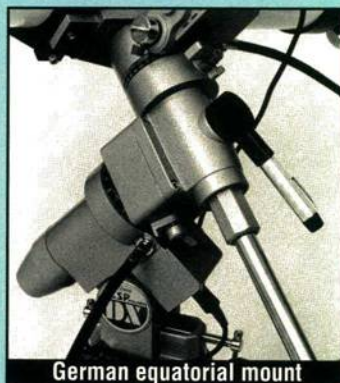
Schmidt-Cassegrain



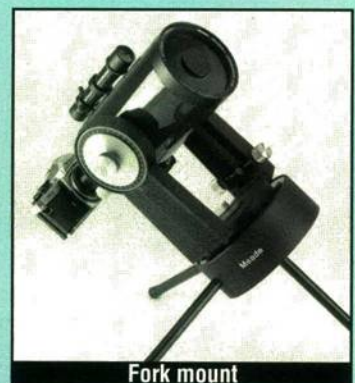
A quality alt-azimuth mount



Dobsonian style mount



German equatorial mount



Fork mount

Telescope Terminology

Amateur astronomy has a jargon all its own. Here are definitions for some of the most commonly used telescope buzz-words.

Aberrations: A unique set of optical distortions or imperfections inherent in a telescope's design. In well-made telescopes, these distortions are minimized to acceptable levels.

Achromatic: The standard type of lens in a refractor. It has two lens elements in the main lens that are matched to reduce chromatic aberration (unfocused color around bright objects).

Apochromatic: A refractor with a 3-element lens system or special fluorite glass that reduces color fringing even further. Called "apochromatics" or "apos" for short, these are among the finest optical systems you can buy.

Catadioptric: A telescope whose optical system combines a mirror with a correcting lens. Examples are the



A 2-inch star diagonal and eyepiece

Schmidt-Cassegrain, the Schmidt-Newtonian, the Maksutov, and Takahashi's Hyperbolic Astrographs.

Clock Drive: An electric motor that drives an equatorial mount to track the stars automatically. Some motors operate off 110-volt AC, some off low-voltage DC.

Coma: An aberration found in fast f /ratio Newtonian reflectors. It turns stars into flying seagull patterns at the edge of the field.

Department Store Telescope: Any mass-marketed small telescope (usually a low-quality refractor) sold with exorbitant claims of magnification.

Diffraction-Limited: A freely used term that means optics so good they are limited only by the wave nature of light and not by any flaws in the surface accuracy of the lenses or mirrors.

Drive Corrector: A device for varying the speed of a drive motor. Often included with DC motors, but extra with AC synchronous motors.

Eyepiece: The small ocular lens you

actually look through. You change magnifications by changing eyepieces. Extra eyepieces are the first accessories most people need to buy.

f /ratio (focal ratio): An all-important characteristic of any telescope, f /ratio is the focal length divided by the aperture. For example, an 8-inch aperture telescope with a focal length of 80 inches is an " $f/10$ " telescope.

Fast Telescope: Any telescope whose f /ratio is $f/3.5$ to $f/6$. These telescopes yield lower powers and wider fields than "slow" f /ratio scopes, making them popular for deep-sky observing. They are often more compact. Photographically, fast scopes also provide smaller, brighter images for shorter exposures of deep-sky objects. However, slow f /ratio scopes often have better quality optics and sharper images.

Field of View: The angular field of a telescope. Even at low powers, most scopes have a field no more than 1° wide, two Full Moon diameters. Wide-angle "rich-field" scopes can have fields of 2° to 3° .

Finderscope: A low-power sighting scope with a field of 4° to 6° used for locating objects and centering them in the narrow field of the main telescope.

Fluorite: An artificially grown crystalline substance that is used in place of glass as one of the lens elements in some high-quality refractors. Its properties can help eliminate chromatic aberration.

Focal Length: The length of the light path from the mirror or lens to the focus point. On refractors and Newtonians, this distance is roughly the same as the length of the tube. On Schmidt-Cassegrains and other telescopes with "folded" light paths, the effective optical focal length is much longer than the actual tube length.

Light-Bucket: A generic term for any large telescope where sheer aperture for maximum light-gathering power is the most important characteristic.

Light-Gathering Power: The amount of light a telescope can collect. It is proportional to the area of the lens or mirror, not to the diameter. A telescope with an 8-inch diameter mirror has four times (not two times) the light-gathering power of a 4-inch telescope, resulting in images four times brighter.

Magnification: The power of a telescope to enlarge objects. It is calculated by dividing the focal length of the main telescope by the focal length of the eyepiece. For example, a 2,000mm focal length telescope used with a 20mm fo-

cal length eyepiece will give 100 power. The maximum usable power for any telescope is about 50x per inch of aperture. Top power for an 8-inch telescope is about 400x.

Maksutov: A type of telescope that combines a mirror with a steeply curved corrector lens. It is difficult to make well but can provide outstanding images. The legendary Questar is the best-known example of a Maksutov.

Resolution: A telescope's ability to reveal fine detail. A telescope's resolving power is directly proportional to its aperture. Compared to a 4-inch telescope, an 8-inch resolves details twice as small or twice as close together.

Rich-Field Scope: A telescope designed to give a bright image and a



An excellent finderscope

wide field of view. It is ideal for observing Milky Way starfields and large deep-sky objects.

Schmidt-Newtonian: A variation of the standard Newtonian telescope that uses a corrector plate at the front of the telescope. It provides fast f /ratios with reduced coma.

Spotting Scope: A small telescope that usually has a fixed eyepiece for a single magnification or a zoom eyepiece plus a built-in image erector lens. Not suitable for astronomy.

Star Diagonal: A small right-angle prism or mirror essential for comfortable viewing when looking at objects high in the sky through a refractor or Schmidt-Cassegrain.

Wavefront Error: The amount of distortion in the final wavefront reaching the eye through optical systems, often stated as a fraction of a wavelength of light. A total error on the final wavefront of 1/4-wave is acceptable, 1/8- or 1/10-wave is very good, and 1/20-wave is superb. But manufacturers have no agreed-upon standard for measuring these values. Until there is, take all claims of surface accuracy with a grain of salt.

The Pros and Cons

	The Pros	The Cons
Achromatic Refractors (60mm to 5-inch)	Economical in smaller sizes; rugged; easy to aim; usually provide sharp images.	Small apertures have limited light-gathering power; larger apertures exhibit chromatic aberration
Apochromatic Refractors (4- to 7-inch)	Provide high-quality images near perfection; excellent for lunar and planetary viewing; fast models good for wide-field, deep-sky viewing and photography.	Relatively expensive for the aperture; light-gathering power cannot compete with that of larger reflectors; can get quite bulky in sizes over 5 inches.
Equatorial Newtonians (4- to 16-inch)	Large aperture for the money; small sizes are excellent scopes for serious beginners. In f/6 to f/8 designs they are good all-purpose scopes.	Can be very bulky and heavy in large sizes; mirrors require adjustment; mirror surfaces are exposed and can get dirty.
Dobsonian Newtonians (8- to 24-inch)	Biggest aperture for least money; best portability for the aperture; superb for deep-sky observing; easy to set up (no polar alignment); great for dark skies.	Optical quality in low-cost models is a compromise; Dobsonian mount does not track the stars; mirror collimation critical in fast f/ratio models.
Schmidt-Cassegrains (4- to 16-inch)	Very portable for an equatorially-mounted scope; easy to set up and aim; adaptable for astrophotography; expandable systems with many accessories; good general purpose telescopes.	Outperformed by specialized telescopes for planetary (refractors and long-focus Newtonians) and for deep-sky observing (large Dobsonians); corrector plates readily attract dew.

- Do you plan to use the telescope in the daytime for nature studies or birding? Then you want a compact scope like a small refractor or a 4-inch class Schmidt-Cassegrain or Maksutov equipped with an image erecting prism. (Astronomical telescopes always produce upside-down images.) Avoid spotting scopes; they are extremely limited for celestial explorations.

- Are you primarily interested in observing the Moon and planets? (If your skies are light-polluted, you may have no choice.) Then a 4- to 7-inch refractor or a high-quality long-focus (f/7 to f/10) Newtonian reflector is for you.

- Do deep-sky objects turn you on? Then satisfy the urge with a 10- to 20-inch monster Dobsonian scope. But be realistic — can you handle such a telescope by yourself? You may be tempted to buy a large scope, thinking you'll leave it in your car and use it by driving to a dark site. Chances are unless you are really dedicated and have many free nights, the scope will never leave the trunk.

- Are your observing interests eclectic? If you're starting out, you'll want to explore everything the sky has to offer and from a variety of observing sites. A Schmidt-Cassegrain is a good all-round performer in a compact package.

Recommendations

Asking the right questions of yourself should help you narrow your choice to one of the categories of instruments listed below. We have recommended suitable models in each category to get you started on your search. But we suggest you review the Telescope Market Survey starting on page 10 for information on many more models.

Entry Level (\$200 to \$600): At the low end of the price range, the 60mm refractors are common choices. While they have limited light-gathering power and often shaky mounts and poor eyepieces, if your expectations are well-tempered they can serve to get you started. The better models include the Tasco 851TR, the Orion TeleVista, the Meade 226, and

the Jason 307 or 313. For \$450 to \$600, you can get a significant increase in quality. If you can, spend the extra money. The Celestron Firstscope, Meade 323, and Tasco 17TR are all good 80mm refractors. One of the best buys in this price range is the Celestron C4.5 *reflector*. It has a winning combination of aperture and optical quality on a solid equatorial mount.

Serious Beginner (\$600 to \$1,000): If you're prepared to spend a bit more for your first telescope, we suggest Celestron's 4-inch SP-C102 refractor, their SP-C6 Newtonian, or their no-frills Classic 8 Schmidt-Cassegrain. Meade's SN-6 Schmidt-Newtonian and Model 826 8-inch Newtonian are also good general-purpose telescopes. With prices of only \$300 to \$350, the Coulter Odyssey 8- and 10-inch Dobsonians undercut the price range of this category. But the substantial costs for shipping and for essential accessories like eyepieces and a finderscope will add to the expense. Also be prepared to wait several weeks or months for delivery on the popular no-frills Coulter telescopes.

Portable and Versatile (under \$1,000): If you're after a highly totable package, then for under \$1,000 you can get the extremely compact Meade 4-inch 2045D Schmidt-Cassegrain.

Portable and Versatile (\$1,000 to \$3,000): If you cherish compactness and can spend more for optical quality and an extra-solid mount, we suggest the TeleVue 4-inch Genesis or VERNONscope 94mm apochromatic refractors.

Good All-Round Performer (\$1,500 to \$3,000): If you want aperture, then check out the Meade Premier Series or Celestron Schmidt-Cassegrains. For example, you can purchase a low-end Meade Model 30 to start your hobby then upgrade by adding an impressive array of accessories. The Astrophysics Star12-ED refractor has less aperture but boasts superb optics and finish.

Astrophotography Package (\$2,000 to \$5,000): Any of the 8-inch Schmidt-Cassegrain models are well-suited to astrophotography, but the Celestron Ultima 8 stands out with its heavy-

The Good, the Bad, and the Unnecessary

Some features are essential for convenience and performance, others are a detriment, and some are luxuries you can add later.

THE GOOD

Carrying Case: This is an often neglected but all-important accessory if you are transporting a telescope into the field.

Coatings: When applied to lenses, corrector plates, and mirrors these improve light transmission and increase image brightness.

DC Motors: These allow you to run a telescope directly off a battery pack or car battery without the need for extra DC-to-AC invertors.

Orthoscopic or Plössl Eyepieces: These are better quality eyepieces than the Kellner and Huygens eyepieces often supplied as standard equipment.

Slow-Motion Controls: An aid in centering objects, these are required on most mounts (except Dobsonians).

Worm Gear Drive: This usually has a smoother tracking accuracy than spur gear drives. It is better for photography.

THE BAD

0.965-Inch Eyepieces: Often standard on small telescopes, these diameter eyepieces are usually of poor to mediocre quality; 1 1/4 -inch diameter eyepieces are better.

Right-Angle Finders: These cause less of a neck-strain to look through, but they present mirror-image reversed views of the sky, making it very confusing to locate objects. Straight-through finders are preferable.

Small Finders: The 5x24 finderscopes on many small telescopes are often very poor and difficult to see through. 6x30 finders are usually better.

Spindly Mount: The principal flaw of low-cost telescopes (and even some high-priced ones) is a mount and tripod that shakes at the slightest touch. A heavier, larger mount is worth the extra expense.

Sun Filters: Small telescopes are often supplied with a type of filter that screws into an eyepiece. These filters should not be

used — they can crack under the intense heat and let through dangerous amounts of light.

Through-the-Lens Finders: Often found on small refractors, these use a small flip-mirror to allow the finder to look out through the main lens. They often give very dim images.

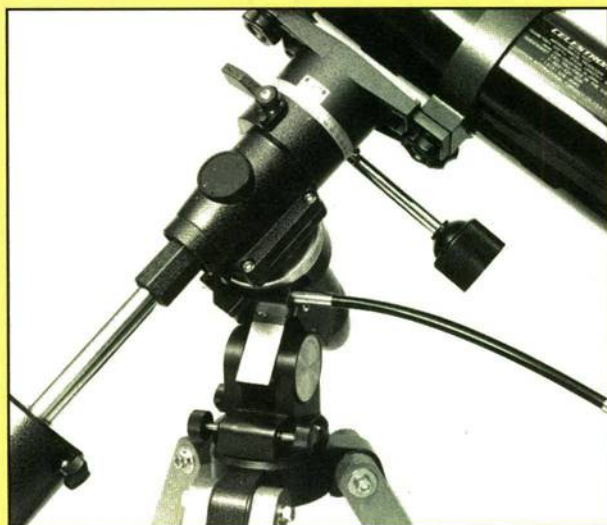
THE UNNECESSARY

2-inch Focuser: These take the giant, 2-inch-diameter barrel eyepieces that are great for low-power, wide-angle views. Unless this is what you are after, a 2-inch focuser is not essential.

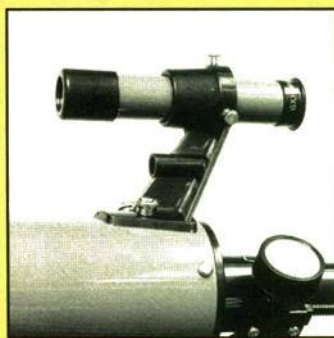
Computers and Digital Readouts: Electronic gadgets can be fun and can even help you find things in the sky, but they are expensive and complicated. You can add them later if you wish.

Electric Focuser: This is a luxury item that allows you to focus without touching and shaking the telescope. It can be added to most major brands of telescopes.

Setting Circles: Often standard on equatorial mounts, they will help you "dial in" a star only if the telescope is precisely aligned with the celestial pole and you understand right ascension and declination coordinates.



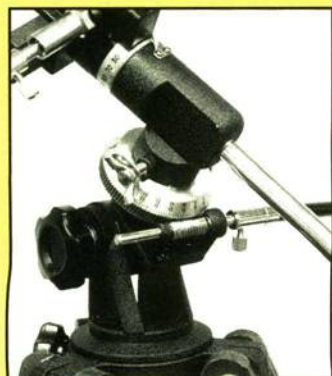
Slow motion controls on a solid mount



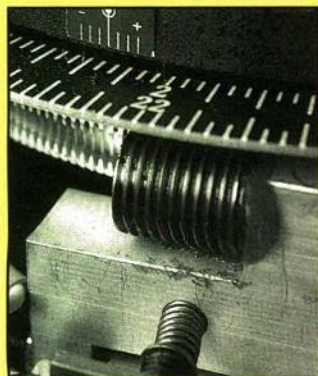
A small, inadequate finderscope



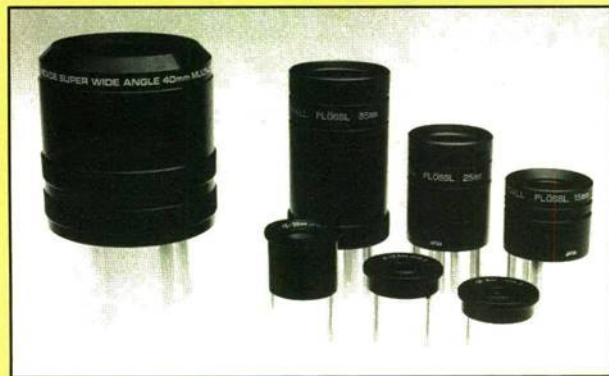
Dangerous eyepiece Sun filters



A flimsy and shaky mount

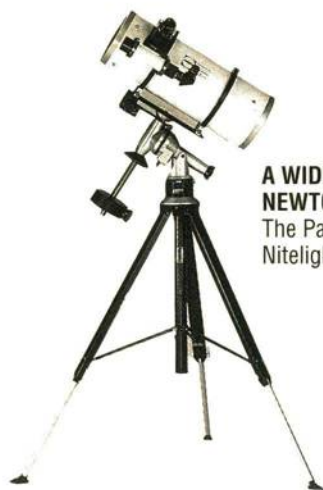


Worm gear drive



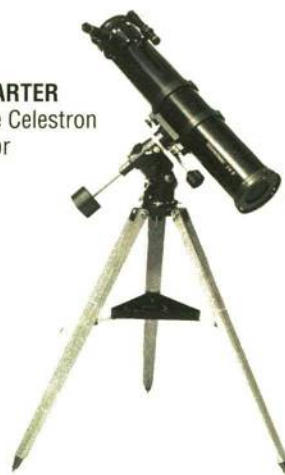
0.965-inch diameter eyepieces vs. 2-inch and 1 1/4-inch eyepieces

A HIGH-QUALITY PORTABLE SCOPE:
The Questar 3.5-inch Maksutov

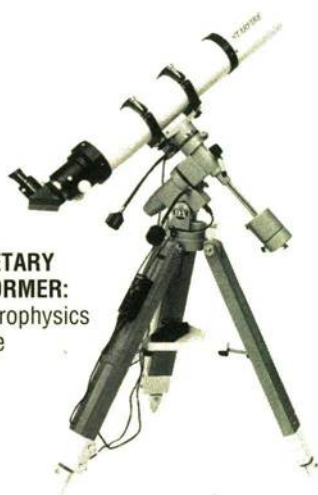


A WIDE-FIELD NEWTONIAN:
The Parks 8-inch Nitelight

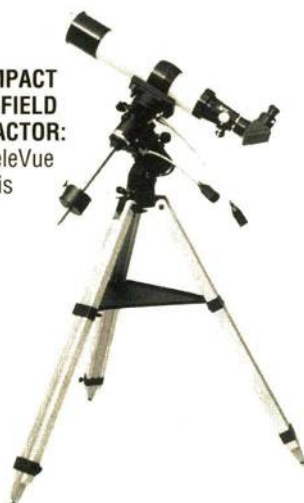
A GOOD STARTER SCOPE: The Celestron C4.5 reflector



PLANETARY PERFORMER:
An Astrophysics Starfire



A COMPACT WIDE-FIELD REFRACTOR:
The TeleVue Genesis



A PORTABLE AND VERSATILE SCOPE:
The Meade 2045 SCT



duty mount and well-designed drive. On the other hand, the f/6.3 Meade Schmidt-Cassegrains require shorter exposure times than traditional f/10 SCTs. The Astrophysics Starfires and TeleVue Genesis boast wide, sharp photographic fields for outstanding deep-sky photos. Eight- to twelve-inch equatorial Newtonians are also favorites among serious deep-sky photographers but these scopes are more awkward to use than Schmidt-Cassegrains.

Planetary Performer (\$2,000 to \$5,000): The Astrophysics refractors, the Celestron SP-C102F Fluorite, and refractors from Dobbins or Cheshire are renowned for the perfect imaging required for seeing the finest planetary detail. But don't overlook traditional long-focus Newtonians such as the Parks 6-inch f/8. They can be as good as many refractors but at a much lower price.

Deep-Sky Light Bucket (\$500 to \$7,500): The larger Coulter Odyssey Dobsonians (the 13- and 17-inch sizes) are incredible values but, again, be prepared to wait a long time for delivery. The Meade DS-10 and DS-16 also give good performance for the dollar. For a better grade of optics, consider the more expensive Dobsonians from small companies like Obsession, Safari, Sky Designs, and Tectron.

Wide-Field Deep-Sky (\$300 to \$2,000): If you have access to dark skies, a fast f/ratio, modest-aperture scope can provide stunning Milky Way views with low-power fields up to 2° to 3° wide. This type of "rich-field" model is excellent as a second scope. This class includes the economical Edmund Astroscan, the TeleVue Oracle and Genesis refractors, the Meade 8-inch Schmidt-Newtonian, the Parks Nitelight mod-

els, and the Coulter Odyssey 8- and 10-inch.

High-Tech Marvel: For the ultimate in a computerized telescope, check out the Celestron Compustar scopes or the Meade Premier 70 or 76 models.

Permanent Observatory Telescope: Large 10- to 16-inch equatorial Newtonians (such as from Parks) or the Celestron 14 or Meade 16-inch SCTs should be permanently mounted to get full use.

A Child's Scope: This is the toughest class of all. The right scope depends on your child's age and level of interest. The scope should be simple, rugged, and easy to aim, and should have an eyepiece at child height. The telescopes mentioned in the Entry Level class may do fine. For a teenager, an 8-inch Coulter Odyssey is another low-cost alternative.

Seeking Advice and Service

A telescope dealer (see the dealer listings starting on page 15) will be able to provide you with personal service and answer your questions, plus take care of exchanges, repairs, or returns if there are problems.

For additional advice, get in touch with a local astronomy club. Attending one of their public star parties can be a wonderful opportunity to see all kinds of telescopes and talk to their owners. But weigh even the advice of long-time amateur astronomers carefully. After owning many instruments over the years, they may have graduated to very specialized and expensive telescopes. It's important to ask them not what kind of telescope they use *now* but what telescope they've made the best use of. Again, the true measure of the quality of a telescope is how often it gets out under the stars. □

ASTRONOMY's

1991 TELESCOPE MARKET SURVEY

Here are the facts and figures on over 160 models of telescopes. For complete information, please write to the companies listed. Most have brochures or catalogs available. Keep in mind that prices, features, and models are subject to change. The prices listed here are the manufacturer's suggested retail; local dealers and mail order houses often discount some brands well below these prices.

REFRACTORS (Lens Telescopes)

	Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyeieces	Finderscope	Focuser size	Weight	Price	Features
ASTRO-PHYSICS, INC. (11250 Forest Hills Road, Rockford, IL 61111; (815) 282-1513)															
Star 12ED	4.7	8.5	2APO	GE	DC	W	✓	✓	✓	—	opt.	2.7	59	\$2,998	ACMPT
4" Starfire	4	8	APO	GE	DC	W	✓	✓	✓	—	opt.	2.7	53	\$2,948	ACMPT
5" Starfire	5	8	APO	GE	DC	W	✓	✓	✓	—	opt.	2.7	65	\$3,605	ACMPT
6" Starfire	6	9	APO	GE	DC	W	—	✓	✓	—	opt.	2.7	103	\$5,520	ACHMPT
7" Starfire	7	9	APO	GE	DC	W	—	✓	✓	—	opt.	2.7	160	\$7,455	ACHMPT
Super Planetary	6	12	APO	GE	DC	W	—	✓	✓	—	opt.	2.7	150	\$6,020	ACHMPT
6" EDF	6	7.3	APO	GE	DC	W	—	✓	✓	—	opt.	4	149	\$9,425	ACHMPT
CELESTRON INTERNATIONAL (2835 Columbia Street, Torrance, CA 90503; (800) 421-1526)															
C60	2.4	13.3	ACH	AA	—	—	✓	—	—	1	5x20	.965	8	\$228	AMT
C60E	2.4	13.3	ACH	GE	—	—	✓	✓	—	1	5x20	.965	12	\$498	AMT
Firstscope 80	3.1	11.4	ACH	AA	—	—	✓	—	—	1	6x30	1.25	18	\$878	AMT
SP-C80	3.1	11.4	ACH	GE	opt.	—	✓	✓	—	1	6x30	1.25	31	\$1,158	AMPT
SP-C102	4	9.8	ACH	GE	opt.	—	✓	✓	—	1	6x30	1.25	37	\$1,998	AMPT
SP-C102F	4	8.8	FL	GE	opt.	—	✓	✓	—	1	6x30	1.25	36	\$4,118	AMPT
CHESHIRE (38 Geraldine Drive, Smyrna, GA 30082; (404) 438-9200)															
3" f/15	3	15	ACH	GE	opt.	—	✓	✓	opt.	3	6x30	.965	28	\$800	AMT
4" f/13	4	13	ACH	GE	opt.	—	✓	✓	opt.	2	6x30	1.25	46	\$2,300	AMT
5" f/5	5	5	ACH	opt.	—	—	—	—	—	1	—	2	16	\$1,695	AM
5" f/15	5	15	ACH	opt.	—	—	—	—	—	1	—	2	32	\$2,495	AM
6" f/5	6	5	ACH	opt.	—	—	—	—	—	1	—	2	27	\$2,695	AM
6" f/15	6	15	ACH	opt.	—	—	—	—	—	1	—	2	52	\$3,695	AM
Also available: Cheshire heavy-duty mounts (\$5,995 to \$7,995) and pier (\$1,295), plus 8", 10", 12", and 16" refractors.															
D & G OPTICAL (6490 Lemon Street, East Petersburg, PA 17520; (717) 560-1519)															
5" f/10 or f/15	5	—	ACH	opt.	—	—	—	—	—	—	8x50	2	19	\$1,195	AM
6" f/12 or f/15	6	—	ACH	opt.	—	—	—	—	—	—	8x50	2	28	\$1,495	AM
8" f/12 or f/15	8	—	ACH	—	—	—	—	—	—	—	8x50	2	40	\$2,995	M
10" f/12 or f/15	10	—	ACH	—	—	—	—	—	—	—	8x50	2	85	\$6,995	M
Also available: German equatorial mount for 5" and 6" tube assembly: \$1,799 with drive and tripod.															
DOBBINS INSTRUMENT COMPANY (5168 Lynd Avenue, Lyndhurst, OH 44124; (216) 449-5730)															
6" f/10	6	10	ACH	GE	AC	W	✓	✓	✓	—	8x50	2	70	\$4,270	AMPT
6" f/15	6	15	ACH	GE	AC	W	✓	✓	✓	—	8x50	2	115	\$8,790	AHMPT
Also available: 6" f/12 and 8", 10", and 12" refractors, air-spaced apochromatic objectives, plus 16" and larger Cassegrain reflectors.															

	Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyeieces	Finderscope	Focuser size	Weight	Price	Features
EDMUND SCIENTIFIC (100 East Gloucester Pike, Barrington, NJ 08007; (609) 547-3488)															
#31-611	2.4	8	ACH	EF	-	-	-	-	-	1	5x24	1.25	7	\$389	AMT
JASON EMPIRE, INC. (9200 Cody, P.O. Box 14930, Overland Park, KS 66214; (913) 888-0220)															
#311 Constellation	2.4	11.6	ACH	AA	-	-	-	-	-	3	5x24	.965	n/a	\$195	AMT
#307 Explorer	2.4	13.3	ACH	AA	-	-	✓	-	-	3	5x24	.965	n/a	\$279	AMT
#313 Discoverer	2.4	15	ACH	GE	opt.	-	✓	✓	-	3	10 x	.965	n/a	\$495	AMT
#324 Saturn	3.1	15	ACH	GE	opt.	-	✓	✓	-	4	6x30	.965	n/a	\$1,204	AMT
MEADE INSTRUMENTS CORPORATION (1675 Toronto Way, Costa Mesa, CA 92626; (800) 854-7485)															
#224	2.4	11	ACH	AA	-	-	✓	-	-	2	5x24	.965	11	\$280	AMT
#290	2.4	11	ACH	GE	opt.	-	✓	✓	-	2	5x24	.965	17	\$500	AMT
#226	2.4	11	ACH	AA	-	-	✓	-	-	2	5x24	.965	12	\$300	AMT
#291	2.4	15	ACH	GE	opt.	-	✓	✓	-	2	5x24	.965	19	\$560	AMT
#312	3.1	11	ACH	AA	-	-	✓	-	-	1	5x24	1.25	22	\$950	AMT
#323	3.1	11	ACH	GE	opt.	-	✓	✓	-	1	5x24	1.25	36	\$1,050	AMT
Also available: #228 and #314 3.1" models finished in brass.															
ORION TELESCOPE CENTER (2450 17th Avenue, P.O. Box 1158, Santa Cruz, CA 95061; (800) 447-1001)															
TeleVista	2.4	11.6	ACH	AA	-	-	✓	-	-	2	5x24	.965	n/a	\$169	AMT
Sky Explorer	2.4	15	ACH	GE	opt.	-	✓	✓	-	2	6x30	.965	n/a	\$329	AMT
PARKS OPTICAL (270 Easy Street, Simi Valley, CA 93065; (805) 522-6722)															
PRT-1	2.4	11.7	ACH	AA	-	-	-	-	-	1	5x24	1.25	11	\$299	AMT
PRT-2	2.4	11.7	ACH	AA	-	-	✓	-	-	1	10 x	1.25	12	\$399	AMT
PRT-46	2.4	15.2	ACH	GE	opt.	-	✓	✓	-	1	10 x	1.25	25	\$499	AMT
SEILER INSTRUMENT AND MANUF. CO., INC. (170 E. Kirkham Avenue, St. Louis, MO 63119; (314) 968-2282)															
aus Jena Telemontor 2	2.4	13.3	ACH	GE	-	-	✓	✓	-	2	-	.965	31	\$1,110	AMT
aus Jena Telemator	2.4	13.3	ACH	GE	AC	✓	✓	✓	-	3	7x42	.965	33	\$1,310	AMT
SIMMONS OUTDOOR CORPORATION (14530 S.W. 119 Avenue, Miami, FL 33186; (305) 252-0477)															
#6330	2.4	13.3	ACH	AA	-	-	-	-	-	2	5x24	.965	n/a	\$250	AMT
#6340	2.4	11.6	ACH	AA	-	-	✓	-	-	4	5x24	.965	n/a	\$300	AMT
#6350	2.4	13.3	ACH	AA	-	-	✓	-	-	3	6x30	.965	n/a	\$350	AMT
SWIFT INSTRUMENTS INC. (952 Dorchester Avenue, Boston, MA 02125; (617) 436-2960)															
#863	2.4	13.3	ACH	AA	-	-	✓	-	-	3	6x24	.965	7.5	\$367	AMT
#859	2.4	15	ACH	GE	opt.	-	✓	✓	-	3	6x30	.965	25	\$650	AMT

Optics Type:

Refractor—ACH (achromat), APO (3-element apochromat), 2APO (2-element apochromat), FL (fluorite apochromat)

Mount Type:

AA (altazimuth), EF (equatorial fork), GE (German equatorial)

Motor Type: 110 volt AC or low voltage DC motor

Gear Type: W (worm gear drive), S (spur gear drive)

Finderscope: Magnification x aperture in millimeters

Focuser Size: Inner diameter of focuser drawtube in inches

Features:

A (antireflection coating on lens or corrector), C (carrying case), E (enhanced reflection coating on mirror), F (fiberglass tube), H (heavy-duty mount), M (metal tube, O (open tube), P (polar alignment finder), R (rotating tube), S (spiral paper tube), T (tripod or pier), X (computer controlled or aided)

opt.: optional accessory

n/a: information not available

	Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyeieces	Finderscope	Focuser size	Weight	Price	Features
TAKAHASHI (c/o Texas Nautical Repair, 2129 Westheimer Street, Houston, TX 77098; (713) 529-3551)															
FC-50	2	8	FL	GE	DC	W	✓	✓	✓	1	6x30	1.34	32	\$1,650	ACMPT
FC-76ES	3	7.9	FL	GE	DC	W	✓	✓	✓	1	7x50	2	44	\$1,995	AMPT
FCT-76	3	6.4	FL	GE	DC	W	✓	✓	✓	1	7x50	2.4	44	\$3,095	AMPT
FC-100H	4	8	FL	GE	DC	W	✓	✓	✓	1	7x50	2.75	68	\$3,995	AMPT
FC-100NH	4	10	2APO	GE	DC	W	✓	✓	✓	1	7x50	2.4	70	\$4,195	AMPT
FCT-100H	4	6.4	FL	GE	DC	W	✓	✓	✓	1	7x50	4	68	\$4,895	AMPT
FC-125NSE	5	8	FL	GE	DC	W	✓	✓	✓	2	11x70	2.7	150	\$8,266	AHMPT
FC-125S	5	8	FL	GE	DC	W	✓	✓	✓	2	11x70	4	198	\$9,995	AHMPT
FCT-125S	5	5.6	FL	GE	DC	W	✓	✓	✓	2	7x50	4	198	\$11,295	AHMPT
FCT-150S	6	7	FL	GE	DC	W	✓	✓	✓	2	11x70	4	213	\$22,995	AHMPT
TASCO (7600 MW 26th Street, Miami, FL 33122; (305) 591-3670)															
#675TR	2.4	15	ACH	GE	—	—	✓	✓	—	3	6x24	.965	13	\$296	AMT
#14F	2.4	13.5	ACH	GE	opt.	—	✓	✓	—	2	10 x	.965	13	\$496	AMT
#17TR	3.1	11.3	ACH	GE	opt.	—	✓	✓	—	3	6x30	.965	32	\$800	AMT
TELEVUE OPTICS, INC. (20 Dexter Plaza, Pearl River, NY 10965; (914) 735-4044)															
Oracle	3	7.4	APO	opt.	—	—	—	—	—	1	—	2	6	\$1,095	ACM
Renaissance	4	5.5	APO	opt.	—	—	—	—	—	1	—	2	13	\$2,195	ACM
Genesis	4	5	APO	opt.	—	—	—	—	—	1	—	2	10	\$2,195	ACM
Also available: Altazimuth and German equatorial mounts starting at \$395.															
T.R. INC. (P.O. Box 65, Mooers, NY 12958; (514) 672-5697)															
60 KT	2.4	15	ACH	GE	opt.	—	✓	✓	—	2	6x30	1.25	n/a	\$1,442	AMT
80 KU	3.1	12.5	ACH	GE	opt.	—	✓	✓	—	2	6x30	1.25	n/a	\$1,599	AMT
80 KW	3.1	15	2APO	GE	opt.	—	✓	✓	—	3	6x30	1.25	n/a	\$2,150	AMT
100 KX	4	13	ACH	GE	opt.	—	✓	✓	—	3	6x30	1.25	n/a	\$2,239	AMT
UNITRON (170 Wilbur Place, P.O. Box 469, Bohemia, NY 11716; (516) 589-6666)															
#128	2.4	15	ACH	GE	AC	W	✓	✓	—	2	6x24	1.25	24	\$1,125	ACMT
#142	3	16	ACH	GE	AC	W	✓	✓	—	3	8x30	1.25	46	\$1,950	ACMT
#152	4	15	ACH	GE	AC	W	✓	✓	—	4	10x42	1.25	100	n/a	ACMT
VERNONSCOPE (5 Ithaca Road, Candor, NY 13743; (607) 659-7000)															
94mm Brandon	3.7	7	APO	AA	—	—	✓	—	—	—	6x30	2	24	\$1,575	AMT
94mm Brandon	3.7	7	APO	GE	AC	✓	✓	✓	—	—	6x30	2	35	\$1,890	AMT
aus Jena Telementor	2.4	13.3	ACH	AA	—	—	✓	—	—	2	—	.965	20	\$695	ACMT
aus Jena Telementor 2	2.4	13.3	ACH	GE	—	—	✓	✓	—	2	—	.965	31	\$1,110	ACMT
aus Jena Telementor	2.4	13.3	ACH	GE	AC	✓	✓	✓	—	3	7x42	.965	33	\$1,310	ACMT
4" aus Jena Semi-Apo	4	10	ACH	GE	AC	✓	✓	✓	—	3	7x42	.965	225	\$10,800	AMT

Optics Type:

Refractor — ACH (achromat), APO (3-element apochromat), 2APO (2-element apochromat), FL (fluorite apochromat)

Reflector — NEWT (Newtonian), CAS (Cassegrain)

Mount Type:

AA (altazimuth), DOB (Dobsonian), EF (equatorial fork), EQ (equatorial), GE (German equatorial)

Motor Type: 110 volt AC or low voltage DC motor

Gear Type: W (worm gear drive), S (spur gear drive)

Finderscope: Magnification x aperture in millimeters

Focuser Size: Inner diameter of focuser drawtube in inches

Features: A (antireflection coating on lens or corrector), C (carrying case), E (enhanced reflection coating on mirror), F (fiberglass tube), H (heavy-duty mount), M (metal tube, O (open tube), P (polar alignment finder), R (rotating tube), S (spiral paper tube), T (tripod or pier), X (computer controlled or aided)

opt.: optional accessory

n/a: information not available

REFLECTORS (Mirror Telescopes)

	Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyepieces	Finderscope	Focuser size	Weight	Price	Features
CELESTRON INTERNATIONAL (2835 Columbia Street, Torrance, CA 90503; (800) 421-1526)															
C4.5	4.5	7.9	NEWT	GE	opt.	-	✓	✓	-	1	5x24	1.25	28	\$838	MRT
SP-C6	6	5	NEWT	GE	opt.	-	✓	✓	-	1	6x30	1.25	38	\$1,358	EMPRT
COULTER OPTICAL (P.O. Box K, Idyllwild, CA 92349; (714) 659-4621)															
Odyssey 8	8	4.5	NEWT	DOB	-	-	-	-	-	1	opt.	1.25	39	\$275	S
Odyssey Compact	10.1	4.5	NEWT	DOB	-	-	-	-	-	1	opt.	1.25	65	\$345	S
Odyssey 1	13.1	4.5	NEWT	DOB	-	-	-	-	-	1	opt.	1.25	100	\$575	S
Odyssey 2	17.5	4.5	NEWT	DOB	-	-	-	-	-	1	opt.	1.25	206	\$1,150	S
EDMUND SCIENTIFIC (100 East Gloucester Pike, Barrington, NJ 08007; (609) 547-3488)															
#31-308	3	6	NEWT	EF	-	-	-	-	-	1	-	1.25	12	\$199	MT
Astroscan 2001	4.2	4.2	NEWT	AA	-	-	-	-	-	1	-	1.25	11	\$379	A
#3011	6	6	NEWT	GE	AC	W	✓	✓	-	1	7x30	1.25	48	\$835	MR
GREAT LAKES INSTRUMENTS (P.O. Box 610, 1971 Haslett Road, Haslett, MI 48840; (517) 339-1151)															
6" f/8	6	8	NEWT	EF	AC	W	-	-	-	1	-	1.25	42	\$475	Kit w/ optics
JASON EMPIRE, INC. (9200 Cody, P.O. Box 14930, Overland Park, KS 66214; (913) 888-0220)															
#327 Observatory	4.5	7.9	NEWT	GE	opt.	-	✓	✓	-	2	5x24	.965	28	\$555	MRT
JIM'S MOBILE INDUSTRIES (1960 County Road 23, Evergreen, CO 80439; (303) 277-0304)															
NGT-18	18	4.5	NEWT	EQ	DC	W	✓	✓	✓	1	8x50	2	180	\$12,900	HOPR
JUPITER TELESCOPE CO., INC. (815 S. U.S. Hwy 1, Suite 4-237, Jupiter, FL 33477; (407) 694-1154)															
Juno 14	14.5	4.5	NEWT	EQ	DC	✓	-	opt.	opt.	-	✓	2	160	\$4,195	EO
MEADE INSTRUMENTS CORPORATION (1675 Toronto Way, Costa Mesa, CA 92626; (800) 854-7485)															
#4420	4.5	8	NEWT	GE	Opt.	-	✓	✓	-	1	5x24	1.25	22	\$700	FRT
#826C	8	6	NEWT	GE	AC	W	-	✓	-	1	6x30	2	75	\$1,640	FRT
#1060	10	6	NEWT	GE	AC	W	-	✓	-	1	8x50	2	208	\$3,490	FHRT
#1266	12.5	6	NEWT	GE	AC	W	-	✓	-	1	8x50	2	273	\$4,850	FHRT
DS-10	10	4.5	NEWT	GE	AC	W	-	✓	-	1	-	2	72	\$1,600	ST
DS-16AB	16	4.5	NEWT	GE	AC	W	-	✓	-	1	-	2	225	\$3,440	ST
OBSSESSION TELESCOPES (923 Stony Road, Lake Mills, WI 53551; (414) 648-2327 am, (414) 648-8284 pm)															
Obsession 20	20	5	NEWT	DOB	-	-	-	-	-	-	-	2	150	\$4,295	O
Obsession 25	25	5	NEWT	DOB	-	-	-	-	-	-	-	2	250	\$8,895	O
OPTICAL GUIDANCE SYSTEMS (2450 Huntingdon Pike, Huntingdon Valley, PA 19006; (215) 947-5571)															
10" Ritchey-Chretien	10	8.5	CAS	GE	AC	W	✓	✓	-	1	8x50	2	167	\$6,200	FT
Also available: 12.5" (\$7,350), 14.5" (\$11,450), 16" (\$12,650), 20" (\$19,990), and 24" (\$29,790), all Ritchey-Chretien Cassegrains.															
OPTICAL RESEARCH CORPORATION (3009 East Forest, Appleton, WI 54915; (414) 734-5006)															
OR-840	8	5	NEWT	EQ	AC	✓	✓	-	-	2	10x50	2	85	\$2,195	AEHMT
Also available: OR-1050 (10" model - \$2,995) and OR-1250 (12.5" model - \$3,995), both with special 3-axis mount with fixed eyepiece position.															

Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyeieces	Finderscope	Focuser size	Weight	Price	Features
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PARKS OPTICAL (270 Easy Street, Simi Valley, CA 93065; (805) 522-6722)

6" f/3.5 Nitelight	6	3.5	NEWT	GE	opt.	-	✓	✓	-	-	8x50	2	30	\$1,099	FRT
8" f/3.5 Nitelight	8	3.5	NEWT	GE	opt.	-	✓	✓	-	-	8x50	2	34	\$1,299	FRT
6" f/8 Precision	6	8	NEWT	GE	opt.	-	opt.	opt.	-	1	6x30	1.25	67	\$799	FRT
8" f/6 Superior	8	6	NEWT	GE	DC	W	✓	✓	✓	2	8x50	2	185	\$2,199	FHRT
10" f/5 Superior	10	5	NEWT	GE	DC	W	✓	✓	✓	2	8x50	2	205	\$2,599	FHRT

Also available: 10" f/3.5 Nitelight (\$2,799), 6" f/6 (\$799) and 8" f/6 (\$1,099) Precision, 12.5" Superior (\$3,599), and 12.5" and 16" Observatory.

SAFARI TELESCOPES (110 Pascask Road, Pearl River, NY 10965; (212) 621-9199)

Safari 18	18	4.5	NEWT	DOB	-	-	-	-	-	-	2	148	\$2,800	OF
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SIMMONS OUTDOOR CORPORATION (14530 S.W. 119 Avenue, Miami, FL 33186; (305) 252-0477)

#6450	4.5	7.9	NEWT	GE	opt.	-	✓	✓	-	2	5x24	.965	28	\$590	MRT
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SKY DESIGNS (4100 Felps, Suite C, Colleyville, TX 76034; (800) 833-1179)

14.5"	14.5	4.5	NEWT	DOB	-	-	-	opt.	-	-	2	88	\$1,900	0
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Also available: 18" (\$2,450), 20" (\$3,450), and 24" Dobsonian models.

STAR LINER (1106 S. Columbus Blvd., Tucson, AZ 85711; (602) 795-3361)

6" Richfield	6	4	NEWT	GE	AC	W	-	✓	-	2	6x30	1.25	70	\$1,995	FHRT
6" Econoline	6	8	NEWT	GE	AC	W	-	✓	-	2	6x30	1.25	55	\$1,380	FRT
8" Econoline	8	8	NEWT	GE	AC	W	-	✓	-	2	6x30	1.25	70	\$1,675	FRT
6" Quality	6	8	NEWT	GE	AC	W	-	✓	-	2	6x30	1.25	70	\$1,890	FHRT
8" Quality	8	7	NEWT	GE	AC	W	-	✓	-	2	6x30	1.25	85	\$2,330	FHRT
8" f/12 Quality	8	12	CAS	GE	AC	W	-	✓	-	3	6x30	1.25	120	\$2,490	FHRT

Also available: 10", 12.5" & 14.25" Newtonians and Cassegrains, combination Newtonian/Cassegrain models, and 16" to 24" Observatory models.

SWIFT INSTRUMENTS INC. (952 Dorchester Avenue, Boston, MA 02125; (617) 436-2960)

#853	4.5	9	NEWT	GE	opt.	-	✓	✓	-	2	5x24	.965	28	\$627	MRT
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TAKAHASHI (c/o Texas Nautical Repair, 2129 Westheimer Street, Houston, TX 77098; (713) 529-3551)

MT-130	5	6.1	NEWT	GE	DC	W	✓	✓	✓	2	6x30	2.25	46	\$1,995	EMPRT
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Also available: MT-160 (6.2" - \$3,550), MT-200 (8" - \$6,195), and MT-250 (10" - \$6,350, no mount), all Newtonians.

TASCO (7600 MW 26th Street, Miami, FL 33122; (305) 591-3670)

#11TR	4.5	7.9	NEWT	GE	opt.	-	✓	✓	-	2	5x24	.965	29	\$480	MRT
#13T	4.5	9	NEWT	GE	opt.	-	✓	✓	-	2	5x	.965	25	\$736	MRT
#8V	5	8	NEWT	GE	opt.	-	✓	✓	-	2	6x30	.965	19	\$1600	HMPRT

TECTRON (2111 Whitfield Park Avenue, Sarasota, FL 34243; (813) 758-9890)

15"	15	5	NEWT	DOB	-	-	-	-	-	-	2	100	\$2,250	0
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Also available: 20" (\$3,700), 25" (\$7,375), and 30" (\$9,500) Dobsonian models.

TELESCOPICS (P.O. Box 98, La Canada, CA 91011; (818) 952-0953)

RFT-6	6	5	NEWT	DOB	-	-	-	-	-	-	1.25	n/a	\$595	EM
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Also available: RFT-8 (\$840), RFT-10 (\$1,705), and RFT-14 (\$3,450) Dobsonian models.

T.R. INC. (P.O. Box 65, Mooers, NY 12958; (514) 672-5697)

100 NQ	4	6	NEWT	GE	opt.	-	✓	✓	-	3	6x30	1.4	n/a	\$1,685	MRT
100 NU	4	10	NEWT	GE	opt.	-	✓	✓	-	2	6x30	1.4	n/a	\$1,708	MRT

CATADIOPTRICS (Mirror/Lens Telescopes)

	Aperture (in.)	f/ratio	Optics type	Mount type	Motor type	Gear type	Slow motion	Setting circles	Speed controls	Eyeieces	Finderscope	Focuser size	Weight	Price	Features
CELESTRON INTERNATIONAL (2835 Columbia Street, Torrance, CA 90503; (800) 421-1526)															
Classic 8	8	10	SCT	EF	AC	S	✓	✓	—	1	6x30	1.25	22	\$1,738	AEM
SP-C8	8	10	SCT	GE	DC	W	✓	✓	✓	1	6x30	1.25	44	\$2,138	AEMT
Powerstar 8-PEC	8	10	SCT	EF	DC	W	✓	✓	✓	1	6x30	1.25	46	\$2,798	ACEMT
Ultima 8-PEC	8	10	SCT	EF	DC	W	✓	✓	✓	2	8x50	1.25	66	\$3,498	ACEHMP
Ultima 11-PEC	11	10	SCT	EF	DC	W	✓	✓	✓	1	8x50	2	93	\$5,590	ACEHMP
C14	14	11	SCT	EF	AC	W	✓	✓	—	4	8x50	2	112	\$13,998	ACEMPT
Compustar 8	8	10	SCT	EF	AC/DC	W	✓	✓	✓	1	8x50	2	42	\$6,498	ACEMPTX
Compustar 14	14	11	SCT	EF	AC/DC	W	✓	✓	✓	4	8x50	2	122	\$21,398	ACEMPTX

MEADE INSTRUMENTS CORPORATION (1675 Toronto Way, Costa Mesa, CA 92626; (800) 854-7485)															
MTS-SN6	6	5	SN	GE	AC	W	—	✓	—	1	—	2	42	\$1,280	AFT
MTS-SN8	8	4	SN	GE	AC	W	—	✓	—	1	—	2	52	\$1,580	AFT
#2045D	4	10	SCT	EF	DC	S	✓	✓	—	1	5x24	1.25	13	\$1,300	ACEM
#2080B	8	10	SCT	EF	AC	W	✓	✓	—	1	6x30	1.25	48	\$1,858	ACEMT
Premier 2080-30	8	10	SCT	EF	DC	W	✓	✓	opt.	1	6x30	1.25	50	\$2,598	ACEMT
Premier 2080-36	8	6.3	SCT	EF	DC	W	✓	✓	opt.	1	6x30	1.25	50	\$2,998	ACEMT
Premier 2080-50	8	10	SCT	EF	DC	W	✓	✓	✓	1	9x60	2	52	\$3,198	ACEMPT
Premier 2080-56	8	6.3	SCT	EF	DC	W	✓	✓	✓	1	9x60	2	52	\$3,598	ACEMPT
Premier 2120-30	10	10	SCT	EF	DC	W	✓	✓	opt.	1	8x50	1.25	70	\$3,398	ACEMT
Premier 2120-36	10	6.3	SCT	EF	DC	W	✓	✓	opt.	1	8x50	1.25	70	\$3,798	ACEMT
Premier 2120-50	10	10	SCT	EF	DC	W	✓	✓	✓	1	9x60	2	73	\$3,998	ACEMPT
Premier 2120-56	10	6.3	SCT	EF	DC	W	✓	✓	✓	1	9x60	2	73	\$4,398	ACEMPT

Also available: Model 2080-70 (\$5,598) & 76 (\$6,398), Model 2120-70H (\$7,198) & 76H (\$7,598), all with computers and other accessories included.

PARKS OPTICAL (270 Easy Street, Simi Valley, CA 93065; (805) 522-6722)															
Jovian-4	4	10	SCT	—	—	—	—	—	—	1	5x24	1.25	3.5	\$899	ACEM

QUESTAR CORPORATION (Route 202, Box 59, New Hope, PA 18938; (215) 862-5277)															
Questar 3.5	3.5	14.4	MAK	EF	AC	S	✓	✓	opt.	2	6x	1.25	7	\$3,370	ACEM
Questar 7	7	14.4	MAK	EF	AC	W	✓	✓	—	2	12x	1.25	53	\$14,450	ACEHM

SWIFT INSTRUMENTS INC. (952 Dorchester Avenue, Boston, MA 02125; (617) 436-2960)															
#854	3.1	12.5	SCT	EF	—	—	✓	✓	—	3	4x20	1.25	9	\$885	CMT
#856	4.5	8.7	SN	GE	opt.	—	✓	✓	—	2	6x30	.965	21	\$798	MRT

TAKAHASHI (c/o Texas Nautical Repair, 2129 Westheimer Street, Houston, TX 77098; (713) 529-3551)															
TSC-225	8.9	12	SCT	GE	DC	W	✓	✓	✓	1	7x50	2	120	\$5,489	AEMPT
ε-160	6.3	3.3	HA	GE	DC	W	✓	✓	✓	—	7x50	2.25	60	\$3,995	AEMPT

Also available: Hyperbolic astrograph models: ε-200 (7.9" - \$6,695), ε-250 (10" - \$7,850, no mount), and ε-300 (12" - \$8,975, no mount).

Optics Type:

Reflector — NEWT (Newtonian), CAS (Cassegrain)
Catadioptric — HA (hyperbolic astrograph), MAK (Maksutov),
 SCT (Schmidt-Cassegrain), SN (Schmidt-Newtonian)

Mount Type: DOB (Dobsonian), EF (equatorial fork),
 EQ (equatorial), GE (German equatorial)

Motor Type: 110 volt AC or low voltage DC motor

Gear Type: W (worm gear drive), S (spur gear drive)

Features: A (antireflection coating on corrector),
 C (carrying case), E (enhanced reflection coating on
 mirror), F (fiberglass tube), H (heavy-duty mount),
 M (metal tube), O (open tube), P (polar alignment
 finder), R (rotating tube), T (tripod or pier),
 X (computer controlled or aided)

opt.: optional accessory

n/a: information not available

TELESCOPE DEALERS

ALASKA

Stewart's Photo
531 West 4th Avenue
Anchorage, AK 99501
907-272-8581

ALABAMA

Camera Amer. Of Montgomery, Inc.
2869 East South Boulevard
Montgomery, AL 36116
205-281-3360

John's Photo & Video
614 4th Avenue North
Birmingham, AL 35203
205-251-1600

Opspec
749 Eastern Manor Lane
Birmingham, AL 35215

Perry Color & Camera, Inc.
2507 5th Avenue South
Birmingham, AL 35233
205-251-2507

ARIZONA

Camera Mart, Inc.
10014 Rodney Parham Road
Little Rock, AZ 72207
501-227-7202

Alpine Trekking
651 South Colb Road
Tucson, AZ 85710
602-885-0494

Guild Camera Shop, Inc.
737 West Camelback Road
Phoenix, AZ 85013
602-264-5808

Mr. Telescope
2071 East Camelback Road
Phoenix, AZ 85016
602-955-5521

Nuart Photo Service
1200 North Eldorado Place, Building E, Ste. 550
Tucson, AZ 85715
602-326-9606

Star-liner Company
1106 South Columbus Blvd.
Tucson, AZ 85711
602-795-3361

Stellar Vision & Astro Gifts
1835 South Alvernon #208
Tucson, AZ 85711
602-571-0877

Tri-city Camera
500 W. Southern Ave., Mesa, AZ 85202
602-964-1380

Wilson Camera Sales, Inc.
3144 East Camelback Road
Phoenix, AZ 85016
602-956-8114

CALIFORNIA

A Nature Walk
228 Main Street
Chico, CA 95928
916-895-1116

Adray's
1809 West Chapman
Orange, CA 92667

Adray's
6609 Van Nuys Boulevard
Van Nuys, CA 91405
818-908-1560

Arlington Phototarium
9590 Magnolia Boulevard
Riverside, CA 92503
714-688-5920

Astro-track Engineering
3900 East Miraloma Avenue
Anaheim, CA 92807
714-630-7381

Barifot Photography
P.O. Box 5839
Tahoe City, CA 95730
916-583-5050

Basic Living Products, Inc.
1321 67th Street
Emeryville, CA 94608

Bel Air Camera
1025 Westwood Boulevard
Los Angeles, CA 90024
213-208-5150

Better Way Foods, Inc.
1620 Monrovia Avenue
Newport Beach, CA 92663
714-546-2244

Beverly Hills Camera Shop
4187 North Beverly Drive
Beverly Hills, CA 90210
213-276-4131

Bogardus & Associates
900 Major Sherman Lane
Monterey, CA 93940
408-625-4486

Bollentini & Company
P.O. Box 876
Aptos, CA 95001
408-688-4712

Boot's Camera Corporation
5587 North Blackstone
Fresno, CA 93710
209-432-0446

Boulevard Camera
1201 Wilshire Boulevard
Santa Monica, CA 90403
213-451-0707

Burt Capel Company
1345 Industrial Avenue
Petaluma, CA 94952

California Academy Of Sciences
Golden Gate Park
San Francisco, CA 94118
415-221-5100

Camera Center
1220 J Street
Modesto, CA 95354
209-524-7361

Camera Company
2201 Larkspur Landing Circle
Larkspur, CA 94939
415-461-3588

Camera Exchange
875 North Palm Canyon Drive
Palm Springs, CA 92262

Camera Kare, Inc.
24601 Raymond Way
El Toro, CA 92630
714-951-8100

Camera Mart
625 B Street, San Diego, CA 92101
619-235-6564

Cameras And Moore
6366 Commerce Boulevard
Rohnert Park, CA 94928
707-584-9166

Canada Camera Shop
930 Foothill Boulevard
La Canada, CA 91011
818-790-6751

Celestial Systems
1255 El Capitan Way
Napa, CA 94558
707-224-3195

Century Telescope Center
12553 Harbor Boulevard
Garden Grove, CA 92640
714-530-3861

Consumer Scientific, Inc.
1411 El Camino Real West
Mountain View, CA 94040
415-967-5515

Cousin's Photo & Appliance
1691 Hancock Street
San Diego, CA 92101
619-293-3137

Crown Camera
1365 Market Street
Redding, CA 96001
916-243-8333

Danville Camera & Sound
201 N. Hartz Avenue
Danville, CA 94526
415-837-0222

Daystar Filter Corporation
3857 "D" Schaefer Avenue
Chino, CA 91710
714-591-4673

Dexter's Camera & Hi-fi, Inc.
P.O. Box 1536
Ventura, CA 93002
805-643-2172

Douglas Telescopes
531 State Street
Santa Barbara, CA 93101
805-966-2888

Earl Watts Optics
26638 Jamaica Lane
Hayward, CA 94545
415-786-2967

Earth & Nature & Science
205 York Street
Nevada City, CA 95959

Earth, Nature, & Science, Inc.
2417 Magowan Drive
Santa Rosa, CA 95405
707-528-2201

Earthworks
3360 Stine Road
Bakersfield, CA 93309
805-398-0808

Empire Camera
600 East Valley Boulevard
Colton, CA 92324

Encino Camera
15928 Ventura Boulevard
Encino, CA 91436
818-990-2060

Ernies Camera Shop, Inc.
201 North Orange Street
Glendale, CA 91203
818-244-8167

Family Photo
967 1st Street, #107b
Encinitas, CA 92024
619-436-0562

Fedco
P.O. Box 2605, Terminal Annex
Los Angeles, CA 90051
213-946-2511

Fireside Camera
2117 Chestnut Street
San Francisco, CA 94123
415-567-8131

Frank's Highland Park Camera
5715 North Figueroa
Los Angeles, CA 90042
213-255-6341

General Machining
1033 North Sycamore Avenue
Los Angeles, CA 90038
213-462-2855

Gluskin's Camera Service
2110 Pacific Avenue
Stockton, CA 95204
209-466-5686

Henley's Photo, Inc.
2000 H Street
Bakersfield, CA 93301
805-324-9484

Hollywood Sights & Sounds
6672 Hollywood Boulevard
Los Angeles, CA 90028
213-463-0772

Home Express
26534 Danti Court
Hayward, CA 94545
415-732-9600

Hughes Aircraft
P.O. Box 1070, El Segundo, CA 90245

I.D.E.A. Optical Testing
2435 G. Village Lane,
P.O. Box 1167
Cambria, CA 93428
818-790-1285

I.Q. Toys, Inc.
7777 Edinger Avenue, #116, Huntington Centre
Huntington Beach, CA 92647
714-373-0049

Jackson Scientific
342 North Euclid Avenue
Upland, CA 91786
714-946-3334

Jaffe's Camera Center
2640 East Main, Ventura, CA 93003
805-643-2231

Jim's Campus Camera, Inc.
766 Higuera Street
San Luis Obispo, CA 93401
803-536-9661

King Photo Supply
749 West Lancaster Boulevard
Lancaster, CA 93534
805-948-8441

Koenig Camera Shop, Inc.
162 Shopper's Lane
Covina, CA 91723
818-339-7302

L. A. Optical
12129 Magnolia Boulevard
North Hollywood, CA 91617
800-843-4780

L. A. Tronics
17921 Ventura Boulevard
Encino, CA 91316
818-344-4104

L. Z. Premiums, Inc.
1162 Saratoga Avenue
San Jose, CA 95129
408-985-9718

La Mesa Camera & Sound
8285 La Mesa Boulevard
La Mesa, CA 92041
619-466-0567

Los Angeles Optical Company
P.O. Box 4868
North Hollywood, CA 91607
818-762-2206

Lumicon
2111 Research Drive #5
Livermore, CA 94550
415-447-9570

Macy's
P.O. Box 7888
San Francisco, CA 94120
415-984-7256

Main Photo Service, Inc.
827 South Main Street
Santa Ana, CA 92701
714-542-3908

Marin Photo & Electronics
1425 Grant Avenue
Novato, CA 94945
415-898-3456

McCurry Camera
P.O. Box 838
Sacramento, CA 95804
916-444-6080

Meade Instruments Corp.
1675 Toronto Way
Costa Mesa, CA 92626

Meadows Camera Shop, Inc.
6506 Pacific Avenue
Stockton, CA 95207
209-477-9421

Mecury Camera
1040 Long Beach Boulevard
Long Beach, CA 90813
213-432-4471

Miko Photo & Sound Company
1259 3rd St., Santa Monica Mall
Santa Monica, CA 90401
213-393-9371

Mitsubishi Electric Sales America, Inc.
P.O. Box 6007
Cypress, CA 90630
714-220-4638

Modern Laboratory Service, Inc.
831 19th Street, Bakersfield, CA 93301
800-637-4462

Montage
23811 Aliso Creek Road, Suite 132
Laguna Niguel, CA 92656
714-643-1611

Monte's Camera Shop
6533 South Green Leaf Avenue
Whittier, CA 90601
213-696-8842

Multi-Camera
149 North Santa Anita Avenue
Arcadia, CA 91007
818-446-4054

Myrick Photographic
598 Fremont Street
Monterey, CA 93940
408-649-1900

Natural Instincts
600 Sycamore Valley Road West
Danville, CA 94526
415-820-8654

Natural Selection
1111 Morro, San Luis Obispo, CA 93401
805-541-6755

Natural Wonders, Inc.
2380 Owen Street
Santa Clara, CA 95054
408-986-0191

Nature Center
2580 Fair Oaks Boulevard #28
Sacramento, CA 95825
916-488-1190

TELESCOPE DEALERS

Nature Company
750 Hearst Avenue
Berkeley, CA 94710
415-644-1337

Nelson Photo Supplies
P.O. Box 85127
San Diego, CA 92138
619-234-6621

Oceanside Photographic Center
1024 Mission Avenue
Oceanside, CA 92054
619-722-3348

Oceanview Instruments
2523 West Pacific Coast Hwy.
Newport Beach, CA 92663
714-646-3275

Odd Assortment
4980 B Pacheco
Pacheco, CA 94553
415-228-4180

Optica b/c Company
4100 Macarthur Boulevard
Oakland, CA 94619
415-530-1234

Optron Systems
15840 East Alta Vista Way
San Jose, CA 95127
408-923-6800

Orion Telescope Center
10555 South De Anza Boulevard
Cupertino, CA 95014
408-255-8770

Orion Telescope Center
2450 17th Avenue
Santa Cruz, CA 95062
800-447-1001

Orion Telescope Center
P.O. Box 1158
Santa Cruz, CA 95061
408-464-0446

Out Of This World
P.O. Box 1010
Mendocino, CA 95460

Pan Pacific Camera
825 North La Brea
Hollywood, CA 90038
213-933-5888

Paul's Photo Inc.
23845 South Hawthorne
Torrance, CA 90505
213-375-7014

Peninsula Scientific Company
P.O. Box 60034
Palo Alto, CA 94306
415-326-4136

PX Camera & Appliance
8889 Adams
Huntington Beach, CA 92646
714-964-1717

Redlands Camera Shop
129 East State Street
Redlands, CA 92373
714-793-2186

Reed's Camera & Video, Inc.
P.O. Box 4157
Walnut Creek, CA 94596
415-934-7207

Rees Camera
928 South Western Avenue #223
Los Angeles, CA 90006

Reseda Photo Service, Inc., c/o Hooper Camera
5059 Lankershim
North Hollywood, CA 91601
818-343-4664

Roseville Hardware, Inc.
203 Harding Boulevard
Roseville, CA 95678
916-782-8402

Russ's Camera, Inc.
1025 State Street
Santa Barbara, CA 93101
805-963-9553

S. Crandall Antiquities
555 Beach Street
San Francisco, CA 94133
415-885-5557

Samy's Camera
7122 Beverly Boulevard
Los Angeles, CA 90036

Santa Anita Camera
1031 South Baldwin Avenue
Arcadia, CA 91007
818-447-1854

Science Shop
11408 Archer Street
San Jose, CA 95112
408-453-5616

Scope City
679 Easy Street
Simi Valley, CA 93065
805-522-6646

Seabright Enterprises
4026 Harlan Street
Emeryville, CA 94608
415-655-3126

Sherman Oaks Camera & Sound
14005 Ventura Boulevard
Sherman Oaks, CA 91423
818-981-2510

Shutterbug Camera
P.O. Box 9155
Santa Rosa, CA 95405
707-576-1456

Silvio's
2809 Pacific Coast Highway
Torrance, CA 90505
213-539-3400

Sky Optical, Inc.
12428 Gladstone Street
Sylmar, CA 91342
818-361-6576

South Bay Photo
21143 South Hawthorne Blvd.
Torrance, CA 90503
213-371-8511

Southside Camera
4425 Ming Ave., Bakersfield, CA 93309
805-835-0280

Spectra-Astro-Systems
6631 Wilbur Avenue, Suite 30
Reseda, CA 91335
818-343-1352

Sports Optics
2612 East Foothill Boulevard
Pasadena, CA 91107
818-577-1501

Star Quest Enterprises
378 South Tustin Avenue
Orange, CA 92666
714-633-8505

Starship Enterprises
2330 Cape Cod Way
Santa Ana, CA 92703
714-558-6121

Studio City Camera Exchange
12174 Ventura Boulevard
Studio City, CA 91604
818-762-4749

Super Locomotion
1213 Elko Drive
Sunnyvale, CA 94089
408-734-5279

Swanlund's Camera Shop
P.O. Box 1009
Eureka, CA 95502
707-442-7041

Syn-Optics
330 Townsend Street, Suite 133
San Francisco, CA 94107
415-541-4937

Telescript Industries Corp.
6735 Odessa Avenue
Van Nuys, CA 91406
818-989-7979

The Good Guys, Inc.
1649 Adrian Road,
Burlingame, CA 94010
415-259-5200

Tony Rose Camera
5666 Calle Real
Goleta, CA 93117
805-967-5621

Tony Rose Camera
436 North Milpas Street
Santa Barbara, CA 93103

Tuttle Cameras
4019 Atlantic Avenue
Long Beach, CA 90807

United Parcel Service,
Ldi Department
P.O. Box 3085
Garden Grove, CA 92642

Unruh's Photography Shop
819 4th Street
Santa Rosa, CA 95404
707-545-1226

Wentling's Camera
1673 Willow Pass Road
Concord, CA 94520
415-685-7655

Woodland Hills Camera
5352 Topanga Canyon Blvd.
Woodland Hills, CA 91364
818-347-2270

Your Favorite Producers
P.O. Box 11325
Marina Del Rey, CA 90295
213-776-3431

COLORADO

A.I.R. Inc.
8401 Baseline Road
Boulder, CO 80303
303-449-3350

Black Forest Observatory
12815 Procupine Lane
Colorado Springs, CO 80908
719-495-3828

Crystal Books & Gifts
307 Main Street
Grand Junction, CO 81501
303-242-5181

Denver Museum Of Natural History
2001 Colorado Boulevard
Denver, CO 80205

DTM Engineering
1035 Delaware Avenue #d
Longmont, CO 80501
303-443-2031

Godec's Photo Supply
9 South Weber
Colorado Springs, CO 87903
303-634-8833

Life Force Technologies
45 Doroux Lane, P.O. Box 755
Basalt, CO 81621
303-927-4781

Martins Star Tracker
633 North South Broadway
Boulder, CO 80303
303-499-0805

Mike's Quality Camera
1637 Pearl Street
Boulder, CO 80302

Nature's Own
411 South Main, P.O. Box 3427
Breckenridge, CO 80424
303-453-2946

Nature's Own
5 East 1st Street
Nederland, CO 80466
303-258-3557

Nature's Own Imagination
Building 21, Suite 140
Fort Collins, CO 80524
303-484-9701

R.S. Instruments
10235 Newton Court
Westminster, CO 80030
303-465-0447

Robert Waxman, Inc.
913 15th Street
Denver, CO 80202
303-623-1200

S & S Optika, Ltd.
5174 South Broadway
Englewood, CO 80110
303-789-1089

Western Camera
P.O. Box 2368, Ft. Collins, CO 80522
303-484-3686

CONNECTICUT

Bob Flynn & Associates
3 Carriage Drive
Avon, CT 06001
203-673-9195

Brainstorms
16 West Main Street
Clinton, CT 06413
203-699-0306

Camera Shop Of New Britain
47 Main Street, New Britain, CT 06051
203-229-2057

Camera Wholesalers
2770 Summer Street
Stamford, Ct 06905
203-357-1467

Camera Works, Inc.
12 Fountain Street
New Haven, CT 06515
203-389-2688

M. K. Super Pictures
84 Connecticut
East Hartford, CT 06108
203-289-1213

Milford Camera Shop, Inc.
9 River Street
Milford, CT 06460
203-878-0156

New England Astro Optics
2 Gordon Street, P.O. Box 834
Simsbury, CT 06070
203-658-0701

Pauli's Wholesale Optics
29 Kingswood Road
Danbury, CT 06811
203-746-3579

Photographic Associates
Box 147, Artillery Road
Middlebury, CT 06762
203-758-9328

Ridgefield Photo Shop
403 Main Street
Ridgefield, CT 06877
203-438-2453

Snap Shack Of Glastonbury
15 Wells Street, Fox Run Mall
Glastonbury, CT 06033
203-633-2311

The Photo Shop
529 Main Street
Torrington, CT 06790

DISTRICT OF COLUMBIA

Smithsonian Institute
600 Maryland Avenue, Suite 295
Washington, D.C. 20560
202-287-3563

World Wildlife Fund
1250 24th Street Northwest
Washington, D.C. 20560
202-293-4800

FLORIDA

1 Hour Photo Lab
P.O. Box 12445
Pensacola, FL 32528
904-432-5874

Abner's Camera Exchange, Inc.
5363 Central Avenue
St. Petersburg, FL 33710
813-321-5363

Barry Burstein-Paba, Inc.
7668 Apple Tree Circle
Orlando, FL 32819
407-352-1396

Beach Photo Service
P.O. Box 3297, Daytona Beach, FL 32018
904-252-0577

Boeder's Camera Repair
2976A Cleveland Avenue
Fort Myers, FL 33901
813-334-8855

Brandon's, Inc.
1819 Kings Avenue
Jacksonville, FL 32207
904-398-1591

Brevard Photo-Video
11478 Byrd Plaza
Cocoa, FL 32922
305-636-2636

Bryan-Olson Corporation
748 West 15th Street
Panama City, FL 32401
904-769-6273

Camera, Inc.
4601 Fowler Street
Fort Meyers, FL 33907
813-275-9996

Coconut Grove
2911 Grand Avenue, Miami, FL 33133
305-445-0521

Colonial Photo & Hobby
P.O. Box 536695
Orlando, FL 32853
407-841-1485

Downtown Exposure
936 East New Haven Avenue
Melbourne, FL 32901

TELESCOPE DEALERS

Executive Toy Store
777 South Flagler Dr., Suite 138
West Palm Beach, FL 33401
407-832-5611

Eyeworks
5720 South Flamingo Road
Cooper City, FL 33330

Great National Camera Machine
1650 North Military Trail, #104
West Palm Beach, FL 33409
407-689-3166

Hialeah Lakes Photo Center
1411 West 49th Street
Hialeah, FL 33012
305-362-3686

Jiffy Photo Center
940 South Federal Highway
Ft. Pierce, FL 33450
407-461-0872

Jim's Photo Shack
4100 East Bay Drive, Clearwater, FL 34624
805-543-2047

Kenin, Inc.
1830 Northeast 163rd Street
North Miami Beach, FL 33162
305-940-7804

Lebaron
2519 East Sunrise Boulevard
Ft. Lauderdale, FL 33304
305-561-4305

Max's Gun Shop, Inc.
72 South Yonge Street
Ormond Beach, FL 32074
904-762-3172

Merritt Photo Center
103 Merritt Square, Merritt Island, FL 32952
305-453-0033

Museum Of Arts & Sciences, Inc.
1040 Museum Boulevard
Daytona Beach, FL 32014
904-255-0285

Museum Of Science & History
10225 Gulf Life Drive
Jacksonville, FL 32207
904-396-7062

Peninsular Marine
1221 East Madison Street
Tampa, FL 33602
813-223-4619

Phil's Camera Service
11517 South Dixie Highway
Miami, FL 33156
305-238-7842

Rowlab Science Center, Inc.
P.O. Box 10156, Jacksonville, FL 32247
800-426-0924

Sarasota Camera Exchange, Inc.
1055 South Tamiami Trail
Sarasota, FL 34237
813-366-7484

Sharpshooters Photographic
1034 West Hillsborough Avenue
Tampa, FL 33603
813-237-2289

Summit Instruments
23723 Southwest 133 Avenue
Princeton, FL 33032
305-258-2253

Sunwest Space Systems
P.O. Box 20500, St. Petersburg, FL 33742
813-577-1062

Tallahassee Camera Center
2800 Apalachee Parkway
Tallahassee, FL 32301
904-877-1152

Top Gun Electronics
3267 East Colonial Drive
Orlando, FL 32803
407-894-2432

Universal Studios Florida
1000 Universal Studio Plaza
Orlando, FL 32819
407-363-8112

Vogel Sales, Inc.
7465 Southwest 115 Street
Miami, FL 33156
305-233-5134

GEORGIA

Camera Country Usa
270 Hilderbrand Drive, Atlanta, GA 30328
404-256-2595

Coke's Camera Center
P.O. Box 4704
Macon, GA 31213
912-746-3286

J.B. Coke & Company
735 Cherry Street
Macon, GA 31213

Robert Manns & Associates
877 Glenbrook Drive
Atlanta, GA 30318
404-352-3679

Wolf Camera, Inc.
1706 Chantilly Drive Northeast
Atlanta, GA 30324
404-633-9000

Worldwide Camera
7805 Abercorn Street
Savannah, GA 31406
912-354-4762

Camera Bug
1799 Briarcliff Road
Atlanta, GA 30306

HAWAII

Francis Camera Shop, Inc.
1450 Ala Moana Center, #1110
Honolulu, HI 96814
808-946-2879

Maul Kwik Photo
275 Kaahumanu Avenue
Kahului, HI 96732
808-877-7702

Rainbow Camera, Inc.
802 Fort Street
Honolulu, HI 96813
808-531-4618

IOWA

Camera Corner
1501 Plaza Place
Muscatine, IA 52761
319-391-6851

Camera Land, Inc.
210 Jefferson Street
Burlington, IA 52601
319-752-4153

Floyd's Sporting Goods
4359 Merle Hay Road
Des Moines, IA 50310
515-276-3498

Gillum Camera Service
2911 Merle Hay Road
Des Moines, IA
515-274-1080

Henry Louis, Inc.
506 East College Street
Iowa City, IA 52240
319-338-1105

Ita, Inc., Regency West Three
4800 Westown Pkwy., Suite 300
West Des Moines, IA 50265
515-224-3400

Omni Optiks
6013 Crown Lane
Des Moines, IA 50311
515-279-8890

Palmer Drug Company
2600 Dodge
Plaza 20 Shopping Center
Dubuque, IA 52001
319-583-5786

Peoples Hardware
2026 East Ridgeway
Waterloo, IA 50702
319-234-6813

Photo Pro
4444 1st Avenue Northeast
Cedar Rapids, IA 52402
319-395-9121

Photo Visions
3220 Division
Burlington, IA 52601
319-754-4888

Porter's Camera Store, Inc.
P.O. Box 628
Cedar Falls, IA 50613
319-268-0104

University Camera
4 South Dubuque
Iowa City, IA 52240
319-337-2189

IDAHO

Camera Corral
515 Sherman Avenue
Coeur D'Alene, ID 83814
208-664-2420

Camera-Video Center
West 296 Sunset, Sunset Mall
Coeur D'Alene, ID 83814
208-664-2323

Idaho Camera, Inc.
P.O. Box 1685
Boise, ID 83702
208-377-3686

Scientific Wizardry
9925 Fairview Avenue
Boise, ID 83704
208-377-8575

ILLINOIS

Able Camera & Video
4331 West Lincoln Hwy
Matteson, IL 60443
708-747-1212

Action Camera & Lab
4826 West 79th Street
Burbank, IL 60459
312-424-6667

Adler Planetarium Store
1300 South Lakeshore Drive
Chicago, IL 60605
312-332-0312

American Science Center
601 Linden Place
Evanston, IL 60202
312-475-8440

Astro Pysics
7470 Forest Hill
Rockford, IL 61107
815-282-1513

Bennett Brothers, Inc.
30 East Adams
Chicago, IL 60603
312-263-4800

Burt Wicke & Associates
P.O. Box 169
Creston, IL 60113
815-758-9853

Card 'n Camera
300 South Mc Lean Boulevard
Elgin, IL 60120
312-397-8600

Community Camera
112-114 North Evergreen
Arlington Heights, IL 60004
312-253-1530

Cosmic Connections, Inc.
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Chicago, IL 60622
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217-344-3434

Elliott's Camera Shop
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Hammacher Schlemmer
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Chicago, IL 60610

Helix Limited
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Chicago, IL 60607
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Komat Scientific, Inc.
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La Salle Photo Service, Inc.
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Rockford, IL 61108
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Galesburg, IL 61401
309-342-6149

Northcenter Camera
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Addison, IL 60101
312-628-1650

P. J.'s Camera & Photo, Inc.
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Glen Ellyn, IL 60137
312-790-1133

Peoria Camera Shop
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Peoria, IL 61614
309-693-9191

Sears, Roebuck & Company
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Chicago, IL 60680
312-875-8051

Sheldon Faworski
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Union, IL 60180
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Shutan Camera Company
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Chicago, IL 60606
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Stern's Camera & Sound Center
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Winnetka, IL 60093
312-446-6830

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Camera Hut
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Indianapolis, IN 46254
317-297-1498

Computer Nook
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Martinsville, IN 46151
317-342-0420

Dave's Camera Mart, Inc.
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Hammond, IN 46320
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Dill Camera Shop
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Mishawaka, IN 46544

Jack's Camera Shop
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317-282-0204

Jorgensen's
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Fort Wayne, IN 46804
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Lawndale Camera Shop
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Evansville, IN 47715

Roberts Distributors, Inc.
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Indianapolis, IN 46225

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10895 Lowell, Suite 150
Overland Park, KS 66210
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Felix Camera Stores, Inc.
8787 Metcalf Avenue
Overland Park, KS 66212
913-642-6799

Leon Crooks Studio & Camera
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Parsons, KS 67357
316-421-1800

Mann's Studio & Camera Shop
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McPherson, KS 67460
316-241-3714

Omnisphere & Science Center
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Wichita, KS 67211
316-682-1921

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Southwest Photo
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Wolfe's Camera
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Boston, MA 02109
617-227-7255

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Fitchburg, MA 01420
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617-426-7092

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Vineyard, MA 02568
617-693-6624

Frank Krauth Company
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South Weymouth, MA 02190
617-331-3795

Harvard Camera Centers
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Harvard, MA 01451
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Iris Photo, Thomes Market
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Northampton, MA 01060
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Worcester, MA 01610

L.B. Wheaton's
Lincoln Plaza
Worcester, MA 01605
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Woburn, MA 01888
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Science Park
Boston, MA 02114

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617-994-9653

Newtonville Camera, Inc.
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Newtonville, MA 02160
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Waltham, MA 02154
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Chevy Chase, MD 20815
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301-953-2000

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Baltimore, MD 21211
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Proudfoot's Oakland Pharmacy
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Oakland, MD 21550
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Ritz Camera Centers, Inc.
6711 Ritz Way, Beltsville, MD 20705
301-953-9611

Service Photo Supply, Inc.
401 Washington Avenue
Towson, MD 21204
301-296-1717

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Bangor Photo Services
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Bangor, ME 04401
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207-799-6120

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20219 Carlyle
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Home Appliance Mart
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Ann Arbor, MI 48103

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301 South Livernois Road
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Grand Rapids, MI 49506

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Pontiac, MI 48053

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Muskegon, MI 49444
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616-946-7150

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Fremont, MI 49412
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Grand Rapids, MI 49506

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Rider's Hobby Shop
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Farmington, MI 48024
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616-527-9300

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612-922-2295

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612-560-5415

Dayton Hudson
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Minneapolis, MN 55413
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National Camera Exchange
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612-546-6831

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Golden Valley, MN 55422
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TLE Marketing Corporation
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Minneapolis, MN 55403
612-339-1210

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330 West 63rd Street
Kansas City, MO 64113

Camera & Video Center
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Manchester, MO 63011
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Columbia Photo & Video
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Creve Coeur Camera, Inc.
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Creve Coeur, MO 63141
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Hoag Enterprises, Inc.,
Lawrence Photo Of Springfield
P.O. Box 4406
Springfield, MO 65808
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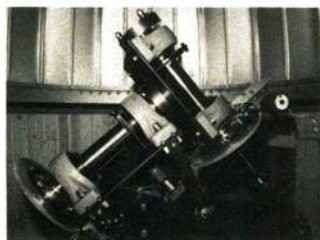
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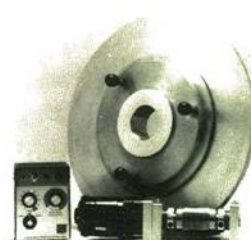
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St. Louis Science Center
5050 Oakland Avenue
St. Louis, MO 63110
314-289-4400

W. Schiller & Company
9240 Manchester Road
St. Louis, MO 63144
314-968-3650

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Deville Camera, Inc.
P.O. Box 12371
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601-956-9283

Franke's Studio
121 North Rollins
Macon, MS 63552
816-385-2412

Observa-Dome Labs, Inc.
371 Commerce Park Drive
Jackson, MS 39213
601-982-3333

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Casebeer Eye Clinic And Optical
3410 Harrison Avenue
Butte, MT 59701
406-494-3154

Jorud Photo Shop
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Helena, MT 59601

Mc Nab Enterprises
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Bozeman, MT 59715
406-587-1300

The Camera Shop
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Bozeman, MT 59715
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Ball Photo
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Elkin, NC 28621
704-527-8400

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919-228-0251

Camera Corner/World-Greensboro
4619 West Market
Greensboro, NC 27407
919-855-3310

Carolina Biological Supply Co.
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Burlington, NC 27215
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Carolina Camera Center
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Greensboro, NC 27408

Foister's Camera Store
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Asheville, NC 28806

Photo Quik One Hour
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Hendersonville, NC 28739
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Charlotte, NC 28205
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Shelby, NC 28150
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Camera Shop
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308-382-3245

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Omaha, NE 68101
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Rockbrook Camera Center
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Omaha, NE 68144
402-397-1171

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Symmes Industrial Park
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603-437-1600

Perfecta Camera Corporation
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Derry, NH 03038
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Dover, NH 03820
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270 Westwood Avenue
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Camera Discount Center
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Paramus, NJ 07652
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Capital Electronics
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Union City, NJ 07087
201-617-1777

Corral Camera
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Northfield, NJ 08225
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Dover Photo & Supply, Inc.
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Dover, NJ 07801
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Barrington, NJ 08007

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Red Bank, NJ 07701
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Brick Town, NJ 08723
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Camera Shop
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Las Cruces, NM 88001
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13140-J Central Southeast
Albuquerque, NM 87123
505-299-3016

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Photo Supply, Inc.
DeVargas Shopping Center
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Stow, OH 44224
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216-725-0011

Jim's Camera
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419-693-1433

Laurel Camera
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Bedford Heights, OH 44146

Mcalister Camera
1454 West Lane Avenue
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Metzger Photo Center
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Cosi Discovery Shoppe, 280 East Broad Street
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Pete's Photoworld, Inc.
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Dublin, OH 43017
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Norman, OK 73069
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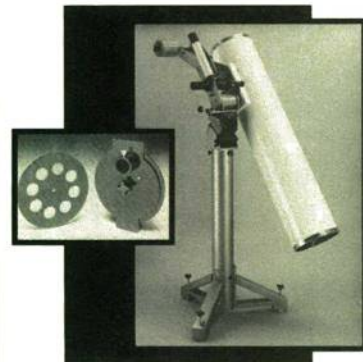
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Declination Slewing	8X speed	No ¹
Continuously Variable Freq. Control	Yes	No
Illuminated Reticle Control	Yes	No
Optional Digital Readouts	Yes ²	No
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